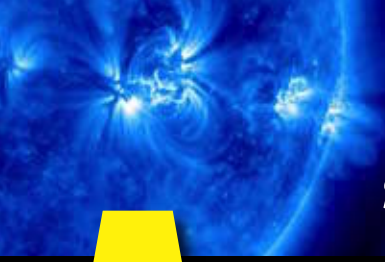

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Image of the Flame and Horsehead nebulas taken by Mark Sibole using a Meade DSI Pro III and Meade 80mm APO.

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True Ritchey-Chrétiens starting at $1295. *That price is NOT a misprint.*

AT8RC Astro-Tech 8" R-C

Up until now, the coma-free performance of a true Ritchey-Chrétien optical system came only in large apertures and typically *started* at well over $10,000 – putting a true R-C astrograph out of the reach of most astronomers.

But **Astro-Tech** asked, "Why should a simple optical tube with two mirrors and no moving parts have to be big and cost five figures?" Sure, Ritchey-Chrétiens use complex hyperbolic mirrors that are much more difficult to make than the simple spherical and parabolic mirrors of Newtonians, Schmidt-Cassegrains, and Maksutovs. And large R-Cs need carbon fiber optical tubes, quartz mirrors, and cooling fans to prevent even the smallest focal length change during long exposure astrophotography.

But Astro-Tech knew that modern computerized mirror grinding was capable of producing complex hyperbolic mirrors with the precision needed, even in small apertures. Buying in quantity could bring the cost of quartz mirrors and carbon fiber optical tubes down to a reasonable price range. And CNC machining the scopes off-shore at a top-quality optical shop could keep the quality up and the manufacturing costs down.

So Astro-Tech partnered with the premier optical shop in Taiwan to produce top-quality *true Ritchey-Chrétien* astrographs at prices the rest of us can afford. It really *is* possible to produce an R-C that you don't have to be a millionaire to own.

Astro-Tech AT6RC: A 6" f/9 ideal for coma-free imaging with webcams, Deep Sky Imager-type cameras, and ST-7/8/9-class CCDs. Aluminum tube, BK-7 mirrors, 1/12th wave or better optics, Crayford focuser, Vixen-style dovetail, dust cover **$1295**

Astro-Tech AT8RC: An 8" f/9 for imaging with 35mm large format (STL-type) CCD cameras and long imaging equipment trains. A light weight/high strength *carbon fiber* tube, quartz mirrors, *dielectric* mirror coatings, 1/12th wave or better optics, genuine *Feather Touch* focuser, case, Losmandy-style dovetail, dust covers **$2995**

Astro-Tech AT10RC: A 10" f/9 with the same features as the AT8RC, but with a larger aperture and two cooling fans. Compare at $14,000 ..... **approximately $4995**

Also in development are 12" and 16" Astro-Tech Ritchey-Chrétiens with similar features as the 10". Prices have yet to be finalized, but they will be sensibly and affordably-priced in line with the 8" and 10" Astro-Tech pricing. Their prices will make you wonder why the competition charges $17,000 to $34,000 for their 12.5" and 16" R-Cs.

TMB triplet apos are in stock and start at $995.

$3999 TMB-130 triplet apo

$1999 TMB-92 triplet apo

The 130mm f/7 **TMB-130** apochromatic triplet, left, is a *Hot Product for 2007*. Unlike other ultra-premium refractors with multiyear waiting lists, this big apo is available now.

The ultra-compact (only 13.25" long!) 92mm f/5.5 **TMB-92** triplet apo, right, expertly fills the void left by the discontinued 90mm Astro-Physics Stowaway (a legendary refractor that sells for up to $6000 on the used market). But the new TMB-92 is only $1999 and it's available now.

Both scopes have collimatable lens cells, FPL-53 ED glass, a genuine *FeatherTouch* dual-speed rotating rack and pinion focuser, compression ring eyepiece holders, carrying case, and more.

$995 TMB-80 triplet apo

The **TMB-80**, right, is an 80mm f/6.3 triplet apo with FPL-53 glass for only $995! It's the first time a genuine TMB-designed refractor has been available at such an attractive price. A true TMB for under $1000? Wow!

The Celestron NexStar SE scopes are four of the best values in astronomy.

$799 Celestron NexStar 5SE 5" Schmidt-Cassegrain

Many of the advanced features in the very complete **Celestron NexStar SE** go-to telescopes were unavailable at *any* price only a few years ago.

For example, their *SkyAlign* go-to computers make astronomy easy as 1-2-3. Just point your scope at three bright stars (or two stars and the Moon or a planet) to line it up on the sky so it can find 40,000 celestial objects for you. You don't even have to know which stars they are!

And their Starbright XLT optical multicoatings give you the brightest images and highest contrast ever so you can see more, and see it better!

Is a Celestron NexStar SE a great value? *Absolutely!*

NexStar 4 SE, 4" Maksutov **$599**
NexStar 5 SE, 5" Schmidt **799**
NexStar 6 SE, 6" Schmidt **999**
NexStar 8 SE, 8" Schmidt **1399**

Competitors? At $1195, the Astro-Tech 102ED has none.

Astro-Tech AT102ED 4" f/6.95 ED doublet **$1195**

No competitive refractor gives you as many standard features for $1195 as the **Astro-Tech AT102ED**.

You get a genuine *Feather Touch* dual-speed micro-focuser custom-made for the 102ED*; illuminated multiple reticle finder*; locking hard case*; dual hinged tube rings with separate 8" dovetail*; 102mm f/6.95 ED doublet optics; retractable dew shield with lock knob*; rotating Crayford focuser; 1.25" and 2" compression ring eyepiece holders; *2-year* warranty*; more.

Competitive scopes just can't compete.

*Features marked with asterisks are either optional or unavailable with some or all competitive refractors.

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We bought every **Meade ETX-125PE** Premier Astro Edition 5" Maksutov Meade had in stock – all 620 of them. We got them at such a good price that we've been selling these $999 retail scopes for only $698. *That is less than dealer cost!*

Smart astronomers snapped up nearly all of them in the first three months.

Meade was so impressed by the number of amateur astronomers who trusted Astronomics to have the best deals in astronomy that they made a final run of 130 Astro Edition 5" ETX-125PE scopes just for us so no one would miss out.

The 5" Astro has an adjustable height tripod with a built-in equatorial wedge, red dot finder, 26mm Super Plössl eyepiece, *Level North Technology* for automatic sky alignment, 30,000+ object AutoStar go-to computer, a full-color deep space image on its optical tube, and more.

When these scopes are gone, only a blue tube version will be available. Except for the tube color, it's identical to this ETX Astro Edition. But the blue tube ETX sells for $999, so you'd better take advantage of the savings while we still have a $698 scope in stock for you.

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You don't have to enter your time or location or memorize a star chart to use a CPC either. Its built-in GPS system and a few anonymous lights in the sky are all you need.

Celestron CPC Schmidt-Cassegrains, with advanced Starbright XLT multicoatings, come with all the features you need to start go-to observing immediately.

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9¼" **CPC925**, with XLT multicoatings **2499**
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Great Astro-Tech eyepiece values from $39.95 to $99.95.

Series 6 20mm

Titan 2" 38mm

The new Astro-Tech eyepieces are good examples of the Astro-Tech philosophy of giving you "more performance for less money."

The **Astro-Tech Series 6** 1.25" eyepieces, above left, have wide 60° and 65° fields at only $39.95 each. Fully multicoated, with fold-down rubber eyecups, they are inexpensive enough to buy two at a time for binoviewer use.

Series 6 – 1.25," 60° field, 8 or 12mm ... **$39.95**
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The **Astro-Tech Titan** 1.25" and 2" eyepieces (the 2" 38mm is to the left) all have wide 70° fields, twist-up rubber eyecups, good eye relief, and none is priced higher than $99.95.

Titan – 1.25", 70° field, 10 or 15mm .. **$59.95**
Titan – 1.25", 70° field, 20mm **69.95**
Titan – 2", 70° field, 26mm **79.95**
Titan – 2", 70° field, 32mm **89.95**
Titan – 2", 70° field, 38mm **99.95**

Are the Astro-Tech eyepieces great values? Does the sun rise in the east? The answer to both questions is yes!

You get a $300 bonus with a Meade LX90's "Ritchey-Chrétien-like" performance.

Meade 8" LX90-ACF **$1999** *freight paid*

Through September 1st, Meade will give you a $299 value mySKY multimedia sky guide or a $338 value 8 x 42mm waterproof binocular and laser pointer *for free* when you buy a Meade LX90-ACF.

Sky & Telescope said that Meade's original Advanced Coma-Free f/8 catadioptric "does indeed perform like a Ritchey-Chrétien." And *Astronomy* said it "delivers Ritchey-Chrétien-like performance at a fraction the cost."

Meade LX90-ACF go-to scopes have an f/10 version of those same coma-free optics. They make "Ritchey-Chrétien-like" optical performance truly affordable.

Meade LX90-ACF catadioptrics with "Ritchey-Chrétien-like" Advanced Coma-Free optics, a full GPS go-to mount, and a $300 equipment bonus start at only $1999!

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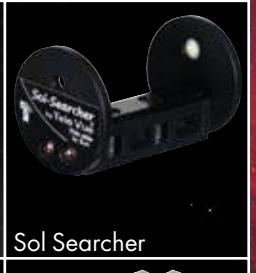
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Discover 10 top Milky Way treats
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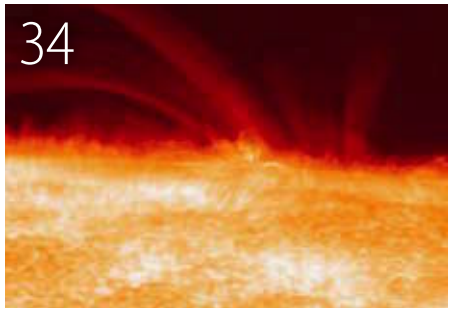

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Join us in Retracing Galileo's Footsteps

by David J. Eicher

Astronomy enthusiasts are beginning to live through one of the greatest anniversaries of our lifetimes. Four hundred years ago, Galileo Galilei turned his crude telescope (which he had built hastily after hearing about existing Dutch instruments) toward the sky. In came the observations of the Moon's cratered surface, sunspots, the stellar nature of the Milky Way, and the moons of Jupiter. Out went the naïve notions of how the universe was composed, and a modern view of the cosmos began to emerge.

During the Galileo anniversary period, we'll cover the stories behind Galileo and his observations extensively (and other topics in the history of astronomy). I'll also be fortunate enough to lead a tour of Galileo's Italy March 26–April 2, 2009, and I invite you to come along to retrace Galileo's footsteps.

Melita Thorpe, MWT Associates of San Jose, California, and *Astronomy* magazine will host this tour that will explore the old-world beauty of Rome and Florence. For anyone who has not been to these legendary Italian cities, the journey will be the trip of a lifetime. For those who have been there, you know how fantastic it will be to return.

The first day will mark an overall tour of Rome that will include the Piazza della Repubblica, the Aurelian Walls, the Roman Forum, Borgheses Park, and the Pantheon, the last being the best preserved ancient building in the world. The next day we'll focus on Vatican City, with a tour of St. Peter's Basilica and the Vatican Museums including the Sistine Chapel with its celebrated imagery.

Leaving Rome, we will go to Tuscany with its beautiful view, and descend upon Florence. On an initial walking tour, we'll see the Duomo with its famous Baptistery and the great bronze doors created by Lorenzo Ghiberti. (The doors on-site are replicas, while the originals can be viewed nearby in the museum.) The tour will also feature the Palazzo Vecchio, Florence's fortress-like town hall.

The fourth day will take us to the Palazzo Medici and then on a spectacular tour of Florence's Science Museum. There you'll see Galileo's early telescopes, one of his original refractor lenses, and his preserved right middle finger, among other relics. We'll then explore the Church of Santa Maria Novella before seeing the celebrated Basilica of Santa Croce. At this last stop, we'll pay tribute to Galileo at his tomb and also see the tomb of Michelangelo.

The trip's next phase will carry us to Galileo's house in Arcetri, south of Florence, the nearby Arcetri Astrophysical Observatory, and San Matteo Convent, where his daughter, Maria Celeste, lived until her death in 1634.

Finally, the group will explore Florence for one more day to see the magnificent Uffizi Gallery, the greatest museum in Italy, and the Palazzo Pitti.

I invite you to join me as we remember Galileo's great contributions to science and explore the majesty of Italy and its wonderful countryside (and cuisine!). For more information, call Melita Thorpe at (877) 707–7827 or e-mail her at tours@melitatrips.com. You can also e-mail me at editor@astronomy.com, and I'll make sure you are sent more information.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 36, Number 9

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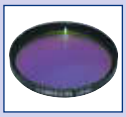

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Fond memories of Arthur C. Clarke

Amateur astronomer Wayne Wooten snapped this image of author and futurist Arthur C. Clarke (right) discussing the Skylab mission with Apollo 9 astronaut Rusty Schweickart in 1973. Wayne Wooten

Readers respond to the March 19 death of world-famous science-fiction author Arthur C. Clarke. His best-known work is the novel and film version of 2001: A Space Odyssey.

I snapped a photo of Arthur C. Clarke aboard the Cunard Adventurer just before the total solar eclipse June 30, 1973, about 1,000 miles east of Trinidad in the Atlantic Ocean. The photo may not be my best, but it is one of my most treasured.

The boat was rocking as Rusty Schweickart and Arthur discussed the potential of the new Skylab missions. Rusty was the first astronaut to test fly the lunar module in space, during the Apollo 9 mission.

When we left Trinidad, the ocean "swell" was anything but that. At dinner that evening, only five of the 500 passengers came to the dining room. Arthur and I were among that select group, but we had only the soup. We then retired to the rail for convenience, where we discussed underwater fossil hunting.

Later in the trip, the Sun and Moon put on a terrific show. Indeed, as Arthur's optimism for humanity often expressed, what a wonderful universe we can enjoy being a part of and getting to know better. — **Wayne Wooten,** professor of astronomy, Pensacola Junior College, Florida

I was very sad to hear of Arthur C. Clarke's death on March 19. I remember being concerned for him the day after Christmas in 2004 when the Indian Ocean tsunami struck Sri Lanka.

I have read the obituaries and eulogies of him, but saw not one reference to his sense of humor. I remember reading a few of his short stories in high school and getting more than a few laughs out of them.

I remember Clarke sitting alongside Walter Cronkite covering the Apollo missions, explaining the various parts of the spacecraft. For years afterward, CBS used a short video clip of him laughing as part of an advertisement for its news coverage.

2001: A Space Odyssey inspired me to study physics, mathematics, and astronomy. I remember going to the theater in Miami Beach, Florida, and paying the astronomical sum of $2 to see the movie. The book inspired me because it explained some aspects of physics that I did not understand at the time. — **Anthony Russo,** professor of physical science, Okaloosa-Walton College, Niceville, Florida

Space-junk risks

China's recent use of a missile to shoot down a satellite has increased the amount of hazardous debris in Earth's orbit. This could create future problems for satellites, spacecraft, and astronauts.

I'm concerned that excess space debris will endanger missions planned by astronomers. A multimillion-dollar mission could be harmed severely by space-junk strikes. — **James T. Struck,** Chicago

For more insight into the space-debris problem, see Richard Talcott's feature article in the June 2008 issue, "How we've junked up outer space." — **Astronomy Editors**

Right telescope, wrong town

I enjoyed the recent article, "Could changing channels tune into alien civilizations?" (May 2008), but I noticed a problem with the caption for the Tatel Radio Telescope on page 40. The National Radio Astronomy Observatory (NRAO) in Green Bank is in West Virginia, not North Carolina.

This site is a venerated location to all involved in radio astronomy. Citing the wrong state for its location is the equivalent of saying that Kitt Peak is in New Mexico or that Mauna Kea is on Oahu. — **William Alexander,** Churchville, Virginia

You are correct. The Tatel Radio Telescope is in Green Bank, West Virginia. We regret the error. — **Astronomy Editors**

Bad dating experience

In your recent article connecting a bolide impact to the end-Permian mass extinction, "250 million years ago, did an asteroid nearly end life on Earth?" (April 2008), most of the space was devoted to the Wilkes Land mascon in Antarctica. Although available dates vary, the Permian extinction event is known to have occurred about 250 million years ago, give or take a million years or two.

Yet, the Wilkes Land structure is known only to be less than 1 billion years old. No evidence is provided to correlate this very poorly dated impact with the very precisely dated Permian extinction. — **Steve Donovan,** Department of Geology, Nationaal Natuurhistorisch Museum - Naturalis, The Netherlands

It's true that the Wilkes Land mascon is not dated precisely. As the article emphasizes, this is the weakest part of any hypothesis that tries to associate the Wilkes Land mascon with the Permian extinction. — **Daniel Pendick,** Associate Editor

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Strange Universe

by Bob Berman

The magic canvas

September's a wonderful month. It's got everything. Dry air, high transparency, Scorpius and the Teapot, the galactic core, even Orion and his friends for post-midnight partyers. As the stars emerge from the suddenly earlier nightfall like the masterful illumination of a Rembrandt, we can inspect the canvas itself — the space between the stars. Here's emptiness rich in both mystery and misconception.

For starters, how much of the sky is occupied? If you've ever camped in the desert under skies wallpapered with endless stars, you'll remember the profusion. No space seemed unfilled. Yet, a straight line slashed across the firmament — a passing satellite will perform this demo — is unlikely to touch a single star. Since 3,000 naked-eye stars are dispersed over the 20,626 square degrees of sky, just one star inhabits each patch the size of 30 Full Moons. Space, not stars, dominates the heavens.

This vacancy is counterintuitive because we focus on objects rather than their environment. The Moon, for example, is perceived as much larger than it really is. Few would guess that it would take 100,000 Moons — packed together — to fill the sky.

In perfect conditions, a moonless sky is almost black, and uniform nearly to the horizon. Its stars appear just a third of a magnitude fainter than they do from space — a difference scarcely detectable to the naked eye. Such rural locales actually offer better views than the astronauts enjoy because the International Space Station's windows and space helmets dim starlight by considerably more than that.

From pristine observing sites with a limiting magnitude of 6.3, the Big Dipper's bowl hosts a half-dozen stars. Such skies appear nearly a million times darker than this page if illuminated by a 100-watt bulb. Each Moon-sized piece of natural sky glows less brightly than a single 10th-magnitude star, beyond even detection by binoculars.

By contrast, half the world now lives in cities, whose eerie steel-gray or synthetic pink firmament offers less than 2 percent of the desert's stars. But you don't have to count stars to compute sky quality. Color alone tells the story.

Major suburbs display a colored zenith tapering to a bright horizon. It'll look even worse in a few months. Winter's snow cover with its albedo of 85 percent bounces up streetlight reflections 6 times more intensely than does grass or asphalt. If you live where folks lock their doors, odds are your Dipper has an empty bowl. For half the world, the Milky Way is a museum curiosity, the northern lights are mythical, and the Moon doesn't even brighten the sky.

For half the world, the Milky Way is a museum curiosity, the northern lights are mythical, and the Moon doesn't even brighten the sky.

Happily, this doesn't make urban astronomy an oxymoron. We save money by buying binoculars that do not further amplify the sky's brightness. While 7x50s were once the astro-standard, such large lenses lighten the sky into an aesthetic nightmare of white dots on a milky background. So, instead, we use 7x35s, 8x30s, or any binocular whose exit pupil (the spec's second number divided by the first) is 4 or 5. This darkens the backdrop.

Next, we select targets with care. Lunar, planetary, and double star observing is as good in bright as in dark skies. Since these objects are perfect for refractors, the latter is a superb urban instrument — and can double as a defensive weapon.

But if the ancient blackness beckons, simply hit the emptiest highway and exit an hour later. The sable space between the stars still lives — in the space between our cities.

When artists try to capture this grandeur, they often blow it. They neglect the cosmic rule that there are far more small objects than large, more dim than bright. To create a realistic space portrait, you'd splatter countless faint dots, a modest number of medium ones, and just a few dazzlers. In dark skies, only one star in 50 outshines the Orion Nebula. A mere 10 percent surpass Alcor, the magnitude-4 "vision test" in the Dipper's handle.

Yet, this motif resonates. Unlike bears and badgers, our eyes can focus on infinity. Our nervous systems probably remember the night sky going back a million years. The natural heavens feel comfortably familiar. Faked celestial scenes, like in the movies, just don't cut it.

So, in this final mild month during the pre-election frenzy, it's good to find an unobstructed sweep of the heavens. We take the hand of someone for whom romance still flows, and spread a blanket on a hilltop, isolated beach, or even in a cemetery. And there's the Milky Way, splitting the night sky in half, as it has for all the Septembers of our lives.

It whispers in its own way that the commotion, like others through the centuries, will pass — and all will be well.

Secret Sky

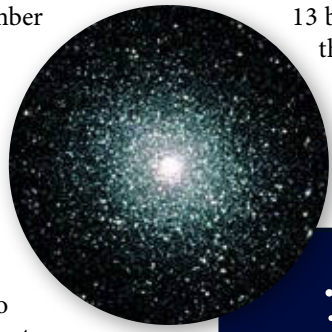
by Stephen James O'Meara

Naked-eye denizens of the galactic deep

Get ready for some heavy breathing, fellow observers, because August and September are good months for hunting down globular star clusters with your unaided eyes. Globulars are senior members of our galaxy.

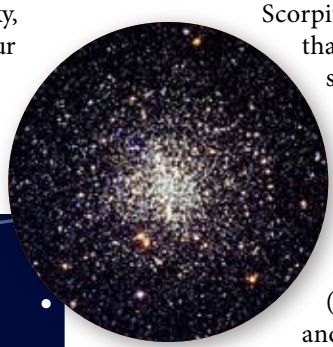
Primordial galactic gases formed many of them in both the Milky Way's halo and bulge. These agglomerations of hundreds of thousands of suns stretch across many tens of light-years of space. They lie so far away, however — thousands to tens of thousands of light-years distant — that most are too faint to see unless you have binoculars or a telescope. But this month, five globulars are reasonably placed for testing your visual acumen after sunset.

To see them, you'll need a dark sky, binoculars, and this magazine by your side for assistance. Use the charts on these pages and the all-sky map at the center of this issue as guides. These views represent how the sky looks at midnight September 1, 11 P.M. September 15, and 10 P.M. September 31 at around 35° north latitude. Also, be ready to breathe deeply and rhythmically, so that your eyes receive a steady stream of oxygen and stay sharp. You'll also need to be patient. I suggest using a lawn chair, recliner, or some other comfortable setup. Most importantly, have fun!

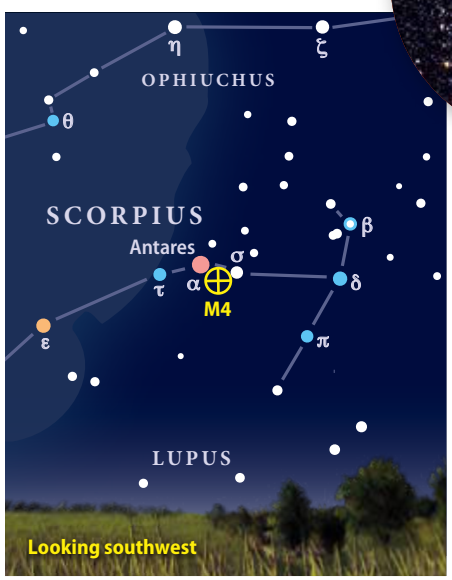


A guarded jewel

Globular star cluster **M4** (NGC 6121) in Scorpius is a low target that requires an early start. You'll find this gem nested midway along, and a tad south of, the brilliant red-supergiant star Antares (Alpha [α] Scorpii) and 3rd-magnitude Sigma (σ) Scorpii. Be sure to find the cluster first in binoculars. Seeing it in the same field of view with fire-orange Antares and icy blue Sigma is a wonder unto itself.



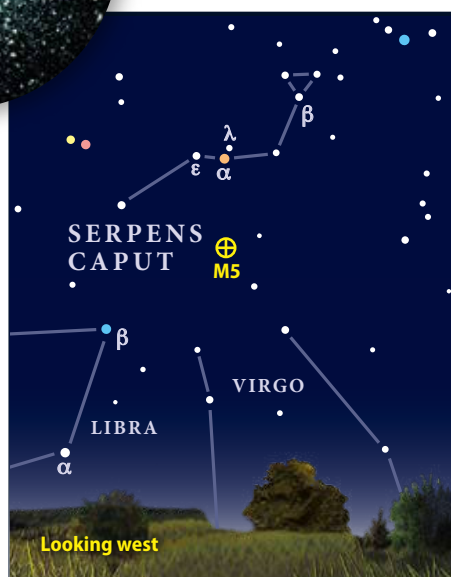
Under a dark sky, the magnitude-5.4 cluster is visible to the unaided eye as a uniform disk of dim light slightly larger than the Full Moon in apparent diameter. You'll need to use keen averted vision and try to negate the glare of brilliant Antares. If you have trouble, try blocking Antares with a distant foreground object, like the roof of a house or a tree, and see if the cluster doesn't pop into view. At a distance of 7,200 light-years, M4 is one of the closest clusters of its kind. With an age of some 13 billion years, it is also among the oldest.



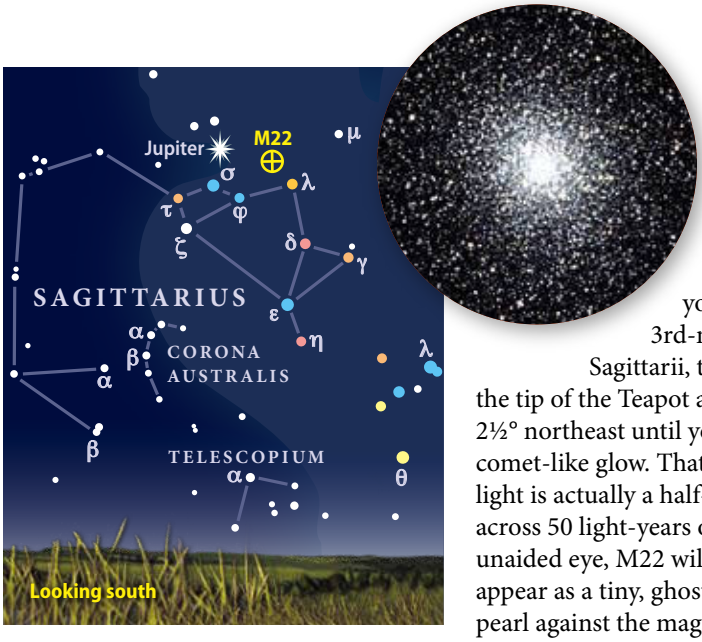
Riding low in September's sky, M4 is easy to locate once you identify Antares. Using averted vision, the naked eye can identify the globular cluster, despite the brightness of Scorpius' Alpha star. *Astronomy*: Roen Kelly; Inset: NOAO/AURA/NSF

The Serpent's surprise

Now raise your sights to Serpens Caput, specifically to 2.5-magnitude Alpha Serpentis. Confirm this golden star with your binoculars. It should be flanked by two 4th-magnitude stars: Lambda (λ) Serpentis is immediately to the northeast and Epsilon (ε) Serpentis is farther away to the southeast. **M5** (NGC 5904) is a little more than one binocular field southwest of Alpha. In binoculars, the 5.7-magnitude cluster should appear as a fuzzy orb of light with a bright starlike core. Also note that M5 lies only 20' northwest of 5th-magnitude 5 Serpentis. The challenge is to separate these two objects with your unaided eyes. Try alternating your gaze from averted to direct vision every few



Sir William Herschel described M5 as "the most beautiful extremely compressed cluster of small stars" in 1786. *Astronomy*: Roen Kelly; Inset: Hillary Mathis, REU Program/NOAO/AURA/NSF



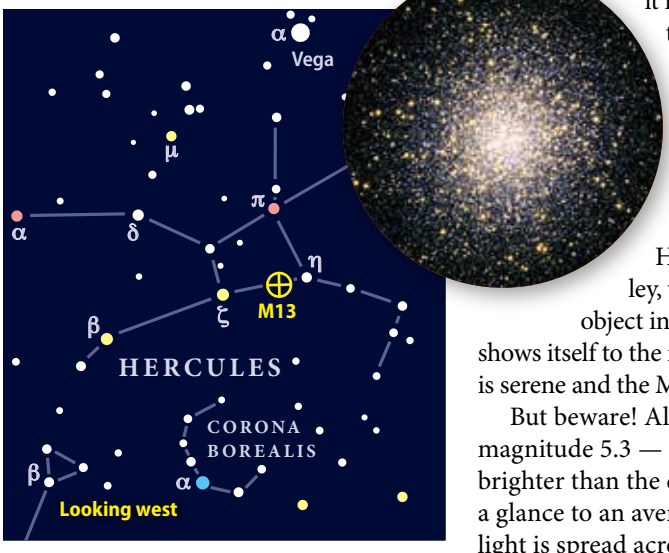
M22 serves as a brilliant "sugar cube" to accompany Sagittarius' Teapot asterism. *Astronomy*: Roen Kelly; Inset: N. A. Sharp, REU program/NOAO/AURA/NSF

seconds for a few minutes. See if the cluster doesn't blink in and out of view.

With an estimated age of 13 billion years, M5 is one of the Milky Way's oldest globulars. It is 24,500 light-years distant and measures some 160 light-years in true physical extent.

A ghostly pearl

Shining at magnitude 5.2, Sagittarius' **M22** (NGC 6656) is the brightest globular cluster readily visible from mid-northern latitudes. Through a telescope, it matches the Full Moon in apparent diameter.



Hercules' Keystone asterism hosts M13, one of the most prominent globular star clusters in northern skies. The 12-billion-year-old Great Hercules Cluster bursts with up to a half million suns. *Astronomy*: Roen Kelly; Inset: NOAO/AURA/NSF

But you'll be looking, once again, for the star cluster's compact core with unaided eyes.

Start by raising your binoculars to 3rd-magnitude Lambda Sagittarii, the golden star at the tip of the Teapot asterism. Now sweep 2½° northeast until you see a smaller, comet-like glow. That clump of diffuse light is actually a half-million suns spread across 50 light-years of space. To the unaided eye, M22 will appear as a tiny, ghostly pearl against the magnificent backdrop of the Milky Way — a stunning vista for the mind.

To see M22, you have to look 10,500 light-years through clouds of interstellar material in the plane of our galaxy, near the galactic bulge. Had its light not been dimmed by dust, the cluster would be at least 0.3, if not 0.5, magnitude brighter.

The cluster king

The **Great Hercules Cluster** (M13) is the most prominent northern naked-eye globular. Just after sunset, it reigns high overhead in the famous Keystone of Hercules asterism.

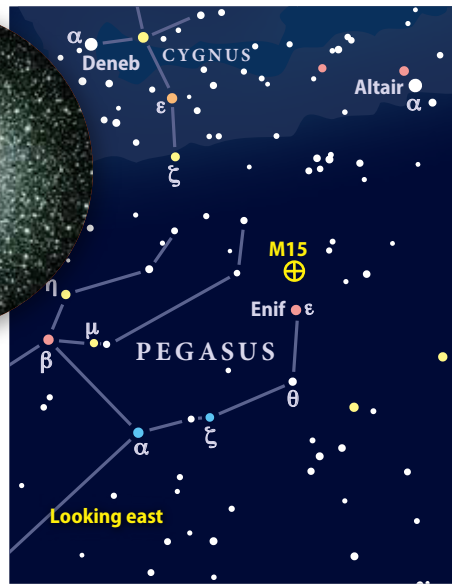
Look about one-third of the way along a line from 3.5-magnitude Eta (η) Herculis to 3rd-magnitude Zeta (ζ) Herculis. Edmond Halley, who discovered the object in 1714, noted that "it shows itself to the naked eye when the sky is serene and the Moon absent."

But beware! Although M13 shines at magnitude 5.3 — a full magnitude brighter than the dimmest stars visible at a glance to an average observer — its light is spread across 20′ of sky. Thus, it is less conspicuous than a star of the same magnitude. With averted vision, M13 is a faint celestial snowball. Spy it, and you'll be seeing a 12-billion-year-old cosmic wonder with up to a half million suns spanning 145 light-years of space.

Why is M13 more conspicuous than M22 in Sagittarius, which is 0.1 magnitude brighter? M13 lies 25,000 light-years distant in the galaxy's halo — high above the dusty plane of the Milky Way near the galactic pole. The contrast between M13 and the sky background then is greater than that between M22 and the blazing Milky Way.

A final challenge

Want to exercise your eyeballs? Then try for the 6th-magnitude **M15** (NGC 7078).



Pegasus' M15 will test the limits of your ability to see with the naked eye. The cluster contains a surprisingly high number of variable stars — more than 110. *Astronomy*: Roen Kelly; Inset: NOAO/AURA/NSF

Start by looking for 2nd-magnitude Enif (Epsilon Pegasi), the topaz nose of Pegasus the Winged Horse. Turn your binoculars to this star, then look 4° northwest for a little globe of diffuse light with a highly condensed center. You're now looking 30,000 light-years distant at a monstrous cluster comprising hundreds of thousands of suns stretched across 160 light-years of space.

To see the cluster with your unaided eyes, you'll have to separate M15 from a star of equal brightness only about 15′ to the east — not a simple task. But several skilled skygazers have done it. So go for the gold!

Let me know how you do with these clusters. E-mail me about your observations at someara@interpac.net.

Sleep, Ulysses On July 1, controllers shut down the Ulysses spacecraft after 17 years of solar observations. Malfunctioning power generators hobbled the craft.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

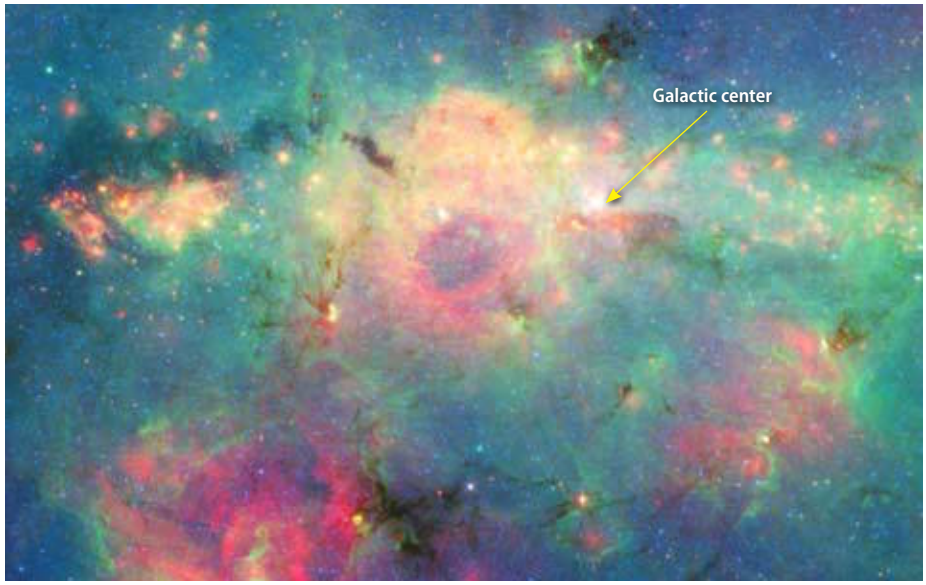
Astronews

New Spitzer mosaic unveils galaxy's heart

Astronomers combined infrared surveys from NASA's Spitzer Space Telescope into a 180-foot (55 meters) panorama of the inner Milky Way. Spanning 13 constellations from Vulpecula to Centaurus, the mosaic provides an unprecedented view of star formation, supernova remnants, bubbles blown by massive stars, hot and cold dust, and ancient stars.

"This project exceeded our wildest expectations," says Robert Benjamin at the University of Wisconsin-Whitewater. He's a member of the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) project, which mapped the Milky Way in infrared wavelengths from 3.6 to 8 micrometers.

At these wavelengths, the Milky Way is virtually transparent. As a result, GLIMPSE astronomers have identified some 200 galaxy candidates.



NASA/JPL/Caltech-SSC and the GLIMPSE and MIPSGAL teams

Core vision. The light of myriad stars in the Milky Way's central region glow blue in this Spitzer Space Telescope image. Green indicates hot gas and red reveals warm dust.

Team scientists revealed the full galaxy panorama June 3 at the American Astronomical Society meeting in St. Louis, Missouri. The image spans 65° of galactic longitude on either side of the galaxy's center but scans only a few degrees above or below the Milky Way's plane. It contains 800,000 images and 4 billion pixels.

The astronomers combined data from GLIMPSE and another galactic-plane survey, known as MIPSGAL. The latter survey used the Spitzer Space Telescope to image the Milky Way at 24 micrometers, an infrared wavelength that revealed hot dust associated with star-forming regions and supernovae. — **FRANCIS REDDY**

16 Merging galaxies come closer to home

18 Mars' dynamic, icy past

19 Black holes wind up galaxy arms

20 Quark nova explains record-breaking blasts

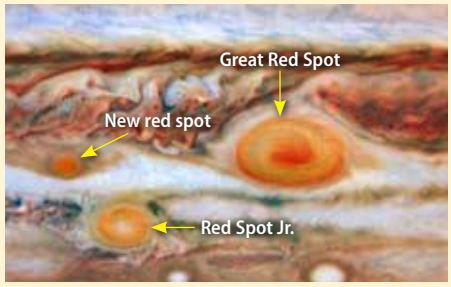
21 Milky Way disarmed

Jupiter's new spot

Jupiter's ever-changing face has a new prominent red spot, marking a rotating storm. In May, astronomers took their first close look at the latest spot on Jupiter with the Hubble Space Telescope and the Keck Telescope in Hawaii.

The new storm lies to the west of its neighboring spots, and is smaller than either the Great Red Spot and Red Spot Jr. The Great Red Spot is hundreds of years old, whereas its sidekick, Red Spot Jr., appeared in spring 2006.

The new red spot is on a collision course with its massive neighbor because they share the same latitude. Big red may absorb the newcomer or simply bat it away. Red Spot Jr. travels in a lower latitude. — **DANIEL PENDICK**



Spot the storm. A new storm system appeared on Jupiter in May. It's on a collision course with the Great Red Spot. Red Spot Jr., which astronomers first observed in 2006, will cruise past its larger neighbor unharmed. NASA/ESA/UC-Berkeley

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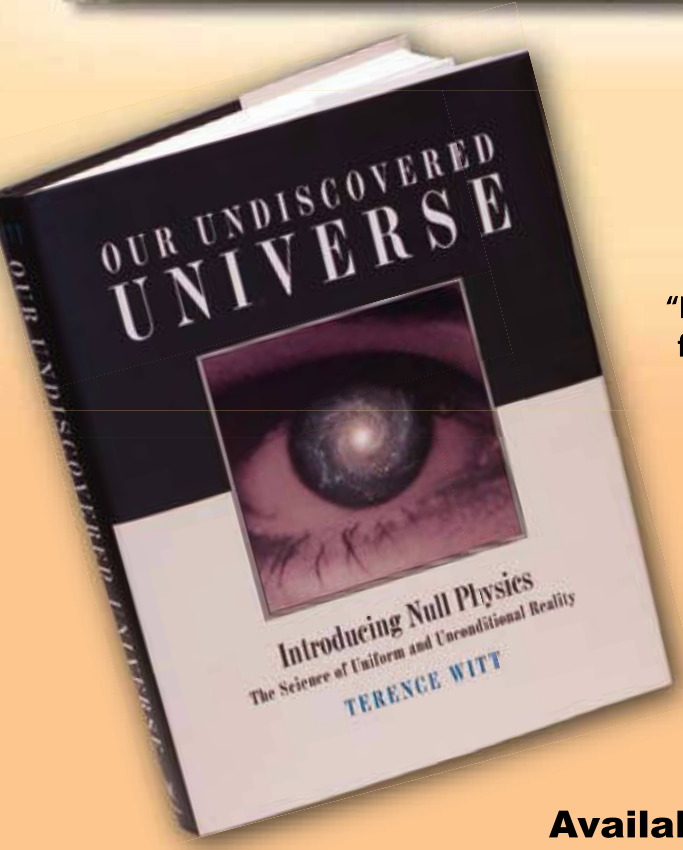

It should be.

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Closer crash. **This ground-based telescope image shows the merging Antennae galaxies and their long tidal tails. They are closer to Earth than previously measured.** Robert Gendler

Merging galaxies come closer to home

The merging Antennae galaxies are closer to Earth than astronomers thought, according to new images from the Hubble Space Telescope. The converging spirals, NGC 4038 and NGC 4039, lie 45 million light-years from Earth. The previous estimate was 65 million light-years.

As the Antennae galaxies merge, their mutual attraction draws out long tails of stars, gas, and dust. The merger is the standard against which astronomers evaluate models of two or more galaxies coming together to form a new galaxy.

To measure the distance to the merger, a team led by Ivo Saviane of the European Southern Observatory used Hubble to observe old, red stars in the merger's southern tail. Stars in the red-giant phase of their evolution emit a standard amount of radiation, like a light bulb rated for a given wattage. Knowing this actual or "intrinsic" brightness allows astronomers to measure distance based on how bright the star appears from Earth.

Saviane says the new distance estimate to the Antennae could improve merger models. "Accurate models require the correct merger parameters, and of these, the distance is the most essential." — **D. P.**

Riding fireballs

Ready to come home. **The International Space Station's solar panels reflect the Sun's glow in an image astronauts captured from the Space Shuttle Discovery. Above and to the right, the Soyuz TMA-9 spacecraft sports a pair of solar sails, as does the Progress 22 resupply vehicle docked to Soyuz' back end.** NASA/STS-116

A fireball meteor is a thrilling surprise to any skywatcher lucky enough to spot one. And in recent decades, several hundred people have actually ridden back to Earth inside artificial fireballs, better known as spacecraft. These trailblazers have brought back thrilling videos and eyewitness accounts of the view from inside, as super-heated plasma enveloped and tried to consume their vehicles.

Sometimes, that exciting fireball ride can get downright frightening if things don't go according to plan. For a few moments April 19, some people on Earth wondered if three crew members from the International Space Station (ISS) — headed home aboard a Russian Soyuz TMA-11 spacecraft — were going to survive the fiery reentry phase of their mission.

The Russian spaceship was coming back from Expedition 16, or the 16th long-term assignment aboard the ISS. Veteran cosmonaut Yuri Malenchenko, the ship's pilot, sat in the center seat. NASA astronaut Peggy Whitson, the flight engineer, sat to Malenchenko's left. South Korean guest cosmonaut Yi So-yeon occupied the third seat.

The TMA-11 mission soon got into serious trouble because the landing capsule wasn't properly oriented for reentry. The bell-shaped Soyuz spacecraft normally hits the upper atmosphere fat-end forward, where the thickest heat shielding is installed.

But, as the initial flames licked around the capsule, it became clear to the crew they were oriented sideways, perhaps even a bit nose forward. Overheating in these less heavily shielded areas could damage the TMA-11's nose-mounted parachutes and radio antennas. In an extreme case, the searing heat could breach the hull and put the crew's lives at risk.

The problem resulted from a mechanical failure that occurred just minutes before the craft hit the atmosphere. The Soyuz normally splits into three sections before reentry. The forward Orbital Module, containing docking hardware and some living space, flies off in one direction. The Equipment Module, containing rocket engines and power systems, goes the opposite way. To ensure these modules don't drift back toward the crew module, cosmonauts normally jettison them at right angles to the flight path.

After separation, the crew cabin remains at a 90° angle to its desired entry orientation, so it must rotate into the proper position. But during reentry, the Equipment Module separation failed, probably because explosive bolts failed to detonate.

As a result, when the crew fired rocket thrusters, the still-connected Equipment Module's extra mass prevented the cabin from rotating. The module's solar wings only added drag, causing the crew cabin to nose more steeply into the atmosphere when it should have been pointed toward space.

Glowing plasma licked at the Soyuz' vulnerable front end. It must have been a frightening sight from inside. Fortunately, the increasing aerodynamic forces on the crew cabin and Equipment Module eventually split them apart. The crew cabin righted itself, and although the landing was rough, the crew survived.

As riders inside an artificial meteor, the crew of TMA-11 experienced a terrifying ordeal. But from the ground, the sight must have seemed exciting and beautiful. The next time I see a bright fireball, I'll remember the TMA-11 crew's rough and dangerous ride from orbit. — **JAMES OBERG**

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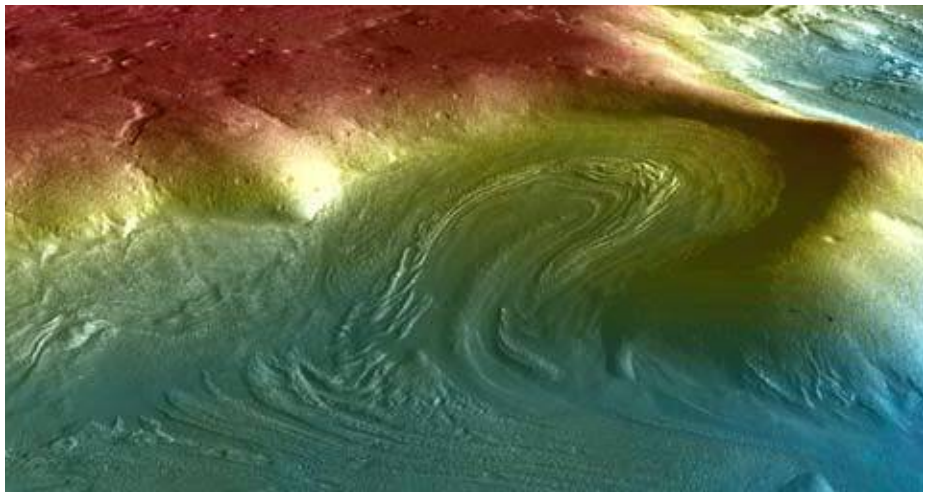

Martian ice age. Without a thick glacier, ice could not have crept uphill into this canyon on Mars and created a looping surface pattern similar to those formed during Earth's ice ages. NASA

Mars' dynamic, icy past

Mars experienced dramatic glaciation relatively recently in its geological history, scientists reported in the May issue of *Geology*. Analysis of images from the Mars Reconnaissance Orbiter (MRO) shows that glacial ice reached a thickness of 0.6 mile (1 kilometer) as recently as 100 million years ago.

The key evidence came from an MRO image of a canyon located at about 41° north latitude. A wide-mouthed box canyon lies on the edge of a gently sloping plain. Its highest wall reaches about 1,000 feet (305 meters) from the canyon floor.

The canyon contains a loop-shaped ridge of rock debris. The pattern is identical to formations on Earth, called moraines, created by ice flowing on the surface.

The problem is that the canyon floor slopes upward from the adjoining plain. Glaciers always flow downhill with gravity, not uphill. Brown University's Jay Dickson and his colleagues think they have it figured out.

The geologists say an ice sheet grew thick enough to flow from the plain into the canyon and completely fill it to the top rim. When the glacier retreated, the ice flowed out of the box canyon. Debris transported by the retreating ice created the moraine-like loop of rocks on the canyon floor today.

Dickson says his findings offer the first evidence of major glacial activity on Mars. "It looks more and more like we are seeing large-scale glaciations similar to what we've seen in the recent history of Earth." — **D. P.**

The Milky Way's youngest supernova

Right after the American Civil War, a star exploded in the constellation Cassiopeia — and now astronomers have accurately dated its glowing remnant, dubbed G1.9+0.3. It is now the most recent known supernova in the Milky Way.

Astronomers observed G1.9+0.3 using NASA's Chandra X-ray Telescope and the Very Large Array (VLA) radio telescope. The object is too obscured by gas and dust to be seen through an ordinary visible-light telescope.

As G1.9+0.3 expands, its shape changes. Comparing 1985 observations by the VLA to those taken by Chandra in 2007 enabled astronomers to make a more accurate estimate of when the blast occurred — about 140 years ago. The next most recent supernova happened in 1680.

Supernova counting is important to determining rates of star birth and death. Based on surveys of the type and number of stars in our galaxy, researchers estimate

Baby star blast. This composite image of supernova remnant G1.9+0.3 combines radio energy (orange) and X-ray energy (blue). NASA/NRAO

about three stars explode in the Milky Way every century. Discovering more remnants like G1.9+0.3 will help to confirm or refute such estimates. — **D. P.**

Phoenix Lander has imaged dust and sand features ever seen on another planet.

Coiled cosmic spring. **The Andromeda Galaxy's tightly wound spiral arms betray an unseen but beefy black hole. The massive object may wind up Andromeda's arms tightly.** Conrad Jung

Black holes wind up galaxy arms

By measuring how tightly spiral galaxies coil their arms, astronomers can estimate the mass of the black holes at their centers. The research appeared May 10 in the *Astrophysical Journal Letters*.

Astronomers have long recognized that many spiral galaxies, including our own Milky Way, sport black holes in their centers millions of times the Sun's mass. Determining the mass of a supermassive black hole requires detailed observations of the stars orbiting near it. The motions of stars close to the galaxy's center reveal how much mass is concentrated there. "That limits you to the nearest 30 or 40 spirals, even with the Hubble Space Telescope," says Marc Seigar at the University of Arkansas, Little Rock.

Seigar led a team that established a predictable relationship between the mass of a galaxy's central black hole and the pitch angle of its spiral arms — a measure of how tightly they coil around the galactic center. He and his colleagues looked at spiral arm angles for 25 galaxies with central black-hole masses established in other studies.

M33, with looser spiral arms angling at 42°, hosts a black hole with a mass of just 1,500 Suns. In contrast, the Andromeda Galaxy (M31), whose central black hole is thought to weigh about 170 million Suns, winds tightly with pitch angles of about 7°. "M31 has the tightest-wound spiral structure of any galaxy we looked at, and it also has the most massive black hole," Seigar says.

Seigar next hopes to apply the technique to very distant galaxies. "We can detect spiral structure in galaxies 8 billion light-years away, maybe a little farther," he says. — **F. R.**

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Cool stuff for a hot ride

In May, NASA conferred its Government Invention of the Year award to engineers at the agency's Ames Research Center. The engineers developed a lightweight heat-shielding material to protect spacecraft during reentry into Earth's atmosphere. The material weighs one-fifth as much as existing heat shields. — **D. P.**

Mars: colder and stiffer inside

The outer crust of Mars doesn't sag under the weight of its north polar ice cap very much, and that means rock in the Red Planet's interior is colder and stiffer than scientists thought. Astronomers surveyed the land beneath the polar ice using radar aboard the Mars Reconnaissance Orbiter. — **D. P.**

Shortlist for TMT site announced

The group evaluating sites for the planned Thirty Meter Telescope has announced a short list of two candidates: Mauna Kea, Hawaii, and Cerro Armazones in Chile's Atacama Desert. With construction planned to start in 2010, the 30-meter telescope should achieve first light in 2018. — **D. P.**

25 years ago in *Astronomy*

September 1983

In September 1983, 5 years had passed since the United States dispatched a spacecraft to another planet. NASA scientist David Morrison's "Return to the planets: A blueprint for the future" discussed NASA's spacecraft dry spell and future plans for planetary exploration.

Morrison promised great technical progress. "By the 21st century," he wrote, "humans could be living in permanent habitations in Earth orbit and on the Moon, while our robot spacecraft explore the solar system."

Although we are still waiting to buy vacation homes on the Moon, NASA's Phoenix Lander successfully touched down on Mars in May with thrusters blazing. This marked the first successful powered landing on Mars in 32 years.

September 1998

10 years ago in *Astronomy*

In September 1998, Ray Jayawardhana, now a contributing editor for *Astronomy*, examined theories of the Moon's birth in "Deconstructing the Moon." At the time, scientists thought the Moon could have formed from rocks and dust separate from our planet, or formed somewhere else in our solar system and later captured by Earth's gravity. Today, scientists favor the impact hypothesis: An object the size of Mars smashed Earth, liberating a vast mass of debris that coalesced to form the Moon.

"Although the computer simulations still can't completely explain all the characteristics of the Earth-Moon system, the giant impact model is now the runaway favorite scenario for the birth of the Moon," Jayawardhana wrote. "After all, it can account nicely for the Moon's makeup and the spin of the Earth-Moon system — two of the most important criteria that any model must meet." — **MEGAN McCHAIN**

Quark nova explains record-breaking blasts

The explosive birth of exotic objects called quark stars may explain super-bright supernovae, say astrophysicists Denis Leahy and Rachid Ouyed of the University of Calgary in Canada. They presented their research on the still-theoretical quark stars June 3 at the American Astronomical Society meeting in St. Louis, Missouri.

Supernovae occur when massive stars collapse and explode. Astronomers observed three stupendously bright examples in 2005–2006. One of the so-called super-luminous supernovae, 2006gy, was the brightest supernova ever recorded. But what unleashed so much energy?

Leahy and Ouyed's computer models suggest a theoretical event called a quark nova can explain the super-luminous supernovae. Supernovae leave behind incredibly dense stellar remnants — neutron stars. Neutron stars pack more than 1.5 times the Sun's mass into a space just 16 miles (27 kilometers) across.

The computer models suggest that if a neutron star is massive enough, pressure in its core could squeeze subatomic particles called quarks into a new type of star. In the process, the neutron star radiates fantastic amounts of energy.

If Leahy and Ouyed are right, the neutron star's energy release, or "quark nova," is what astronomers have been calling super-luminous supernovae. However, nobody has yet confirmed the existence of a real quark star. — **D. P.**

QUICK TAKES

BLACK HOLE BLAST-OFF
Astronomers watched a black hole exit its galaxy at 6 million mph, recoiling after its creation from the merger of two smaller black holes.

COROT NOTCHES FOUR EXOPLANETS
Europe's exoplanet hunting satellite COROT discovered four new planets in 510 days of operations, astronomers announced in May.

SATURN DOES THE WAVE
Astronomers have uncovered a wave-like pattern of temperature change in Saturn's atmosphere that repeats every 15 years.

ORBITAL ORIGAMI
Japan plans to launch a fleet of 8-inch-long (20 centimeters) heat-proof paper airplanes from the International Space Station in 2008 as part of basic engineering research.

MARS' VOLCANIC PAST
Mars Express images suggest that five global volcanic upheavals in the past 3.5 billion years transformed the planet's surface.

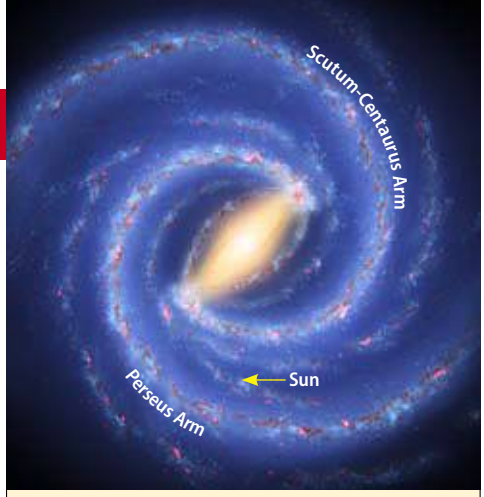
NASA'S NEXT ENGINES
In May, NASA engineers completed first-round testing of the liquid J2-X engine, which will help loft the post-shuttle crew launcher Ares I.

HYDROXYL AHOY!
The Venus Express probe detected hydroxyl molecules in Venus' air for the first time, providing a way to indirectly measure ozone in the hothouse planet's atmosphere.

OBSCURE KNOWLEDGE
A team of European astronomers has calculated that dust blocks about half of all light produced by the universe.

PIPSQUEAK STAR ROARS
NASA's Swift satellite spied a flare thousands of times brighter than those typical of the Sun coming from the dim dwarf star EV Lacertae.

ULTIMATE DIONE ATLAS
Cassini mission scientists have combined 449 super-sharp images of Dione to create the best-yet atlas of Saturn's 700-mile-wide moon.



Revised plan. New observations say the Milky Way has only two major spiral arms, not four as astronomers thought. NASA/JPL-Caltech

Milky Way disarmed

A major new mapping campaign reveals that the Milky Way, our home galaxy, has only two major arms, not four as previously believed. A team of astronomers reported the finding at a June 2 press briefing at the American Astronomical Society meeting in St. Louis, Missouri. Major galactic arms are dense with stars, exhibit a high rate of star formation, and are attached to the galactic core.

Astronomers mapped the arms in part with data from the Spitzer Space Telescope. Spitzer's infrared camera allowed the researchers to peer through the dust that interferes with observations in ordinary optical light. Data from the Very Long Baseline Array, a network of 10 radio telescopes, also contributed to the mapping project. — **D. P.**

Another super-Earth discovered

A planet about three times Earth's mass orbits a brown dwarf star smaller than the Sun, a team of astronomers reported on June 2 at the meeting of the American Astronomical Society in St. Louis, Missouri. The discovery adds weight to the evidence that planets are a common feature in our galaxy. "Our discovery indicates that even the lowest-mass stars can host planets," says team leader David Bennett of the University of Notre Dame.

Theoretical models of planet formation suggest the planet, which lies about 3,000 light-years from Earth, should be made primarily of rock and ice. It orbits its star at approximately the distance Venus circles the Sun.

The team detected the planet with the Microlensing Observations in Astrophysics (MOA) II telescope in New Zealand. The Very Large Telescope in Chile confirmed the super-Earth detection. — **D. P.**

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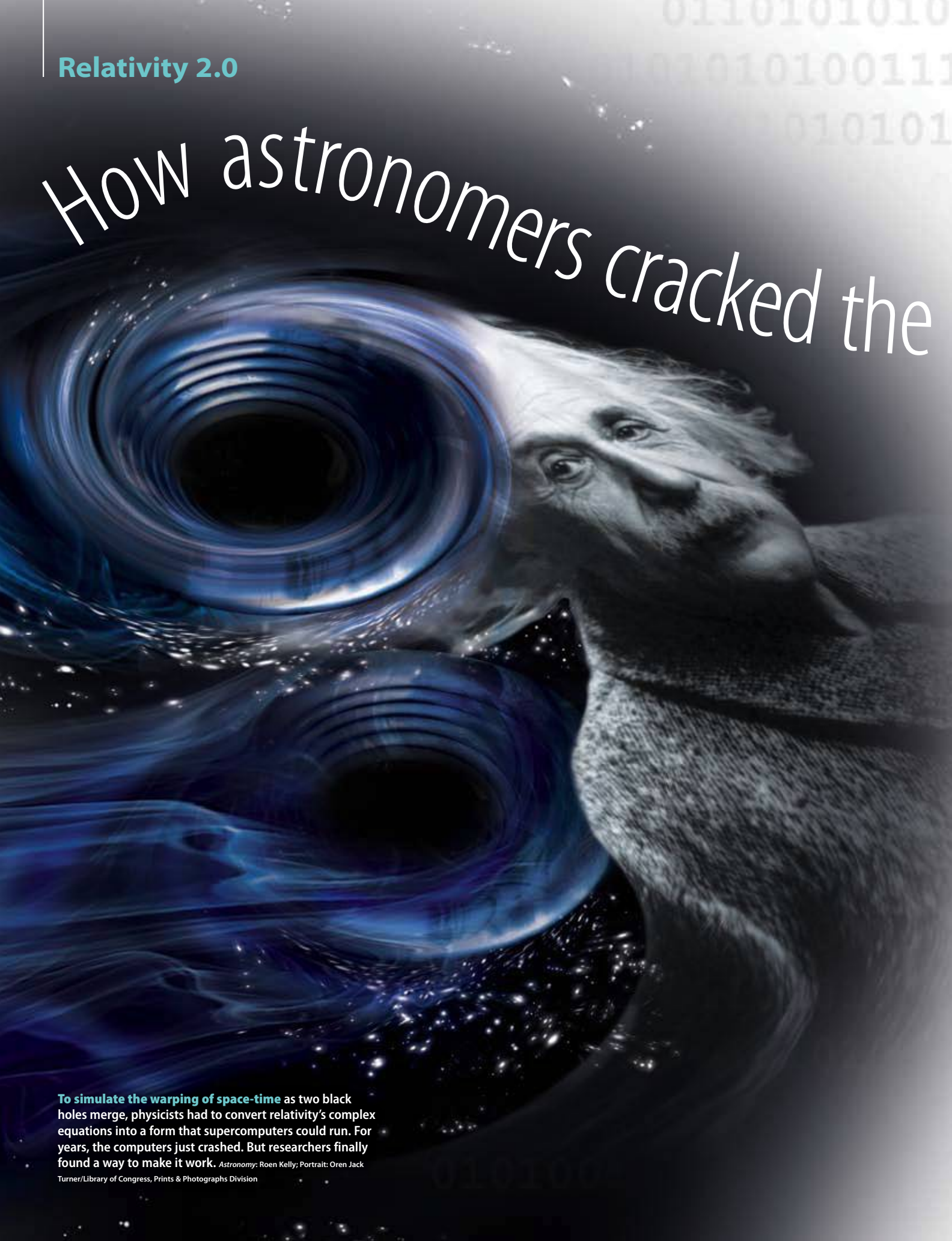
How astronomers cracked the



To simulate the warping of space-time as two black holes merge, physicists had to convert relativity's complex equations into a form that supercomputers could run. For years, the computers just crashed. But researchers finally found a way to make it work. *Astronomy*: Roen Kelly; Portrait: Oren Jack Turner/Library of Congress, Prints & Photographs Division

Scientists are colliding virtual black holes to put relativity to the final test. **by Adam Frank**

Einstein code

Simulating the merger of black holes is no small scientific feat. For one thing, it requires a lot of computing horsepower — the kind you can get only from a supercomputer. It also involves solving the complex, multilayered equations of Einstein's theory of general relativity at lightning speed. Using supercomputers, researchers in the field of numerical relativity hope to shed light on the physics of the most violent events in the cosmos, such as black-hole mergers and colliding neutron stars.

But numerical relativity demands that researchers take on Albert Einstein full bore. Solving the equations of general relativity — Einstein's grand theory of gravity — is difficult enough. The additional challenge is to digitally animate the most complex behaviors hiding inside those equations.

Getting results has become urgent. A new kind of telescope — gravitational wave detectors, built to sense ripples in the fabric of space and time — has recently come on line. These gravity observatories were built specifically to detect events like black-hole mergers. But the telescopes need guidance from computer models to know what sort of signal to look for. This special imperative has made numerical relativity the kind of challenge that draws theorists with a special kind of ambition.

For years, the computer codes at the heart of numerical relativity simulations could do little more than simply crash. All paths seemed blocked; nothing worked. In spite of all the intellectual firepower attracted to the research, and 30 years of work, some theorists were giving up hope. Simulating Einstein's universe might not just be hard — it might be impossible.

But recent breakthroughs in computer modeling by numerical relativists mean the simulations are finally working. They found a way to run Einstein's equations as black holes collide, without crashing their supercomputers. Animations created from the model runs show black holes spiraling into each other and merging while emitting blasts of radiation and rippling gravity waves.

This research has opened a new window on the universe — one in which astronomers can hopefully observe disturbances in space-time as readily as flashes of X rays and visible light.

Adam Frank *is a professor of astrophysics at the University of Rochester in New York. His new book,* The Constant Fire: Beyond the Science vs. Religion Debate*, will be published in January 2009 from University of California Press.*

Within a cloud of hot gas, radio-energy jets emanate from two supermassive black holes (the two bright spots) in the galaxy NGC 1128. Recent observations suggest the black holes will eventually merge into one, radiating a cosmic earthquake of gravitational waves.

X-ray imagery: NASA/CXC/AIFA/D. Hudson & T. Reiprich et al.; Radio imagery: NRAO/VLA/NRL

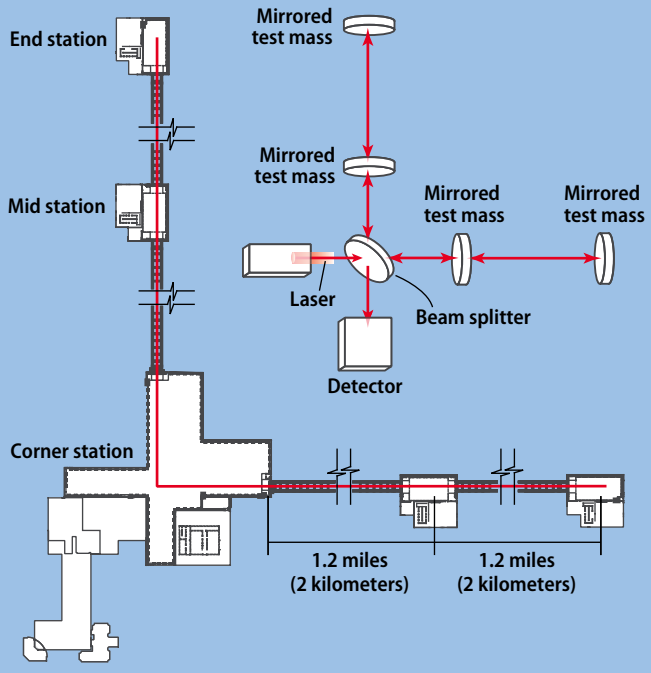
Listening for black holes

On the dusty plains of the Hanford Nuclear Reservation, about 500 miles (800 kilometers) southeast of Seattle stands numerical relativity's reason for existence. It consists of two long vacuum chambers that meet to form an L-shaped gravity observatory. The facility is called LIGO, the Laser Interferometer Gravitational-wave Observatory.

At the Laser Interferometer Gravitational-wave Observatory (LIGO) site near Richland, Washington, astronomers have begun the search for disturbances in space-time. A sister LIGO observatory operates in Livingston, Louisiana. Observations began in 2005. LIGO Laboratory

Sensing gravity waves

Laser Interferometer Gravitational-wave Observatory (LIGO)



Each of the LIGO detectors sends laser pulses down two 2.5-mile (4 kilometers) arms and combines their light. This diagram shows the layout of the Hanford, Washington, observatory. By making laser light travel up and down the arms and interfere with itself, scientists will be able to deduce minute changes in the light's path from a gravity-wave encounter. *Astronomy*: Roen Kelly

The LIGO Hanford Observatory, along with a sister facility, the LIGO Livingston Observatory in Louisiana, represent a new kind of telescope.

LIGO is designed to pick up gravitational waves — ripples on the surface of space-time's ocean that are a key prediction of Einstein's general theory of relativity. Wiggling a mass back and forth produces gravity waves that move across the fabric of space-time. Wiggling a massive, compact object like a black hole creates gravity waves so powerful they can be detected across astronomical distances.

"Gravity waves are the point of LIGO," says Scott A. Hughes, a professor of physics at MIT's Kavli Institute for Astrophysics and Space Research. "The crossed lasers are designed to detect changes in space-time produced by passing gravity waves. But you have to know what to look for."

When people started thinking about LIGO, they realized that the merger of two orbiting black holes would produce a strong signal. A binary system of two massive stars orbiting each other sets the stage for the merger. When the stars go supernova, they each leave behind a black-hole corpse.

The black holes remain locked in orbit around each other. The closer they get, the more they disturb local space-time. The system generates gravity waves that ripple outward. The waves sap orbital energy from the black holes, which then circle each other ever more closely. They eventually merge into a single object in a cataclysm of distorted space-time and radiating gravity waves.

"LIGO should be able to see these mergers," Hughes explains. The LIGO project set researchers on the black-hole merger problem with a vengeance. For years, scientists have been trying to use general relativity to calculate the signals LIGO scientists should look for in their data. A match would mean LIGO has detected a black-hole merger.

Death spiral

There are three phases to a black-hole merger. First, "inspiral" occurs as the black holes circle around each other on an ever-tightening orbit. Until they get close, slight modifications of Newtonian gravitational attraction work just fine.

At the middle phase of the merger, all hell breaks loose. Tracking two black holes as they spiral into collision demands the full-blown equations of general relativity with no tricks or simplifications. The merger also produces the strongest LIGO signal. The melding of two rapidly moving black holes shreds space-time and radiates a torrent of gravity waves from the scene.

Like the inspiral phase, the merger's conclusion is relatively easy to calculate. "You end up with a single black hole," says Hughes. "The event horizon of the merged black hole oscillates for awhile and radiates gravity waves until it stabilizes." This final phase of black-hole merger is called the ringdown.

Accurately reproducing the details of a merger and its gravity wave signature is the grand challenge needed to satisfy

LIGO. Earlier this decade, a merger was the prize everyone was gunning for. Winning that prize meant Einstein's equations would have to be wrestled to the mat.

Einstein's impossible legacy

It's the complexity of relativity theory that makes numerical relativity so hard. To handle a problem like merging black holes, theorists have to solve 10 interwoven equations simultaneously. Take just a few steps into a calculation and you can end up with hundreds of terms — smaller pieces of equations — to follow. It's like doing algebra and calculus in the middle of a tornado.

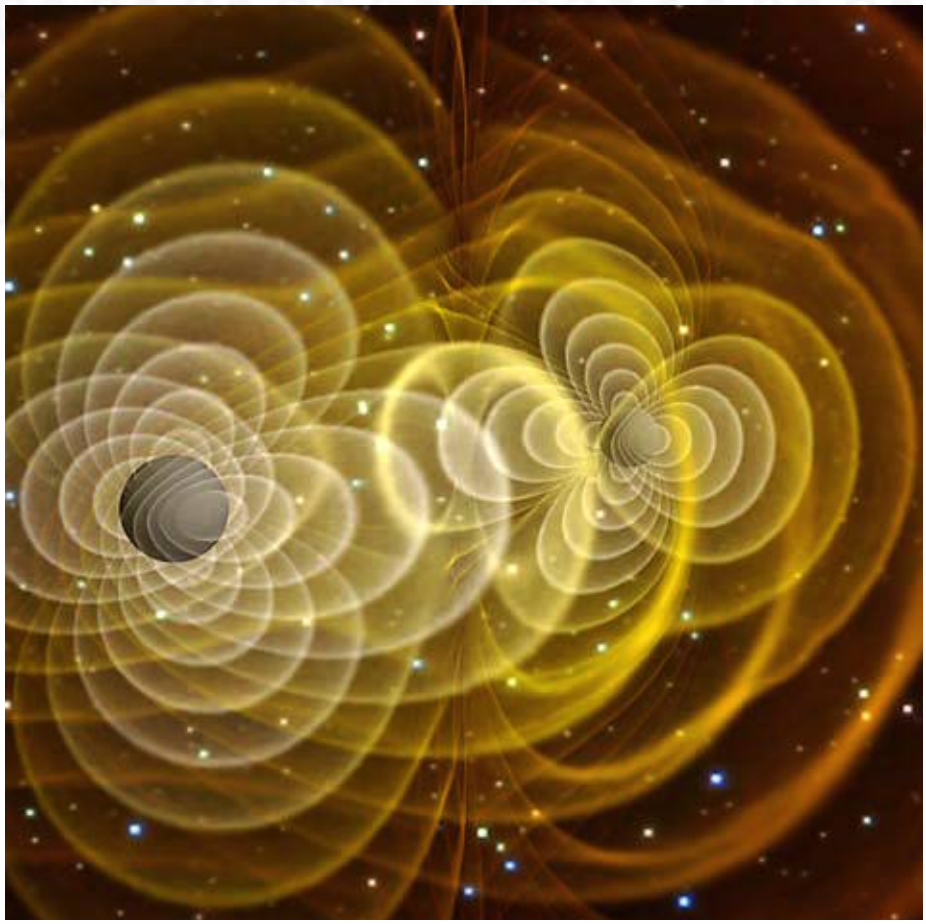
Theorists had to first think of ways to convert the equations of general relativity into a form that computers could swallow. "The first attempt at numerical relativity came in the 1970s," says Joan M. Centrella, chief of the gravitational astrophysics laboratory at Goddard Space Flight Center in Greenbelt, Maryland. "It was really a heroic effort."

Centrella understands such theoretical heroism. She and her research group have worked on numerical relativity simulations for 20 years. The first efforts focused on direct collisions of black holes. The calculations were crude, but they did point the way for a future generation of researchers. To make real progress, scientists would have to figure out how to simulate Einstein's 4-D space-time on a computer and make it work for the most complicated situations.

In general relativity, space and time are intrinsically mixed. All objects in space-time, including you and me, have four dimensions. Each of us occupies and moves through the three dimensions of space and, simultaneously, a fourth dimension of time. That means each person's life history is a four-dimensional object stretching from birth to death. The same principle applies to black holes.

Black hole weirdness

To make it possible to run the equations of general relativity in a computer, researchers had to develop a way to accommodate the complexities of four-dimensional objects. Then, they had to develop a way to visualize the data as 2-D and 3-D animations. This left another major challenge: simulating the black holes themselves.



The intense gravity fields of two black holes merge in a computer simulation performed by scientists at NASA's Goddard Space Flight Center in Greenbelt, Maryland. Astronomers hope to detect gravity waves emitted during black-hole mergers. Christopher Henze/NASA Ames Research Center

Every black hole is surrounded by an event horizon, the point beyond which ordinary radiation cannot escape the object's powerful gravity. The event horizon is the boundary between our universe and the weirdness inside. Anything passing through the horizon exits our world forever. It's no surprise, then, that putting black holes into computer simulations creates problems.

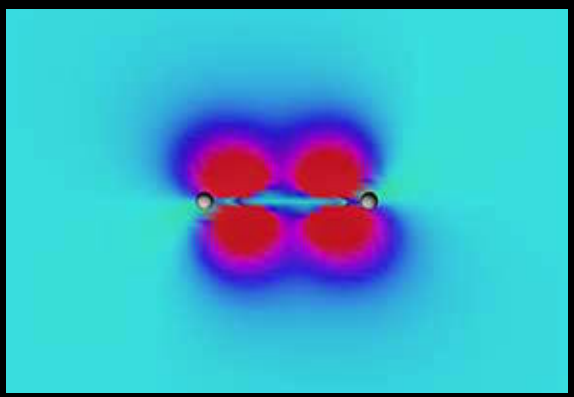
Inside of the event horizon is a place where simulations can't go. Yet, without a way of representing black holes in the model, there could be no numerical relativity. Over the years two strategies emerged to treat the problem. "You can

NASA's Columbia supercomputer is one of the fastest machines of its kind in the world. Tremendous processing power is required to calculate distortions in space-time caused by merging black holes. Tom Trower/NASA Ames Research Center

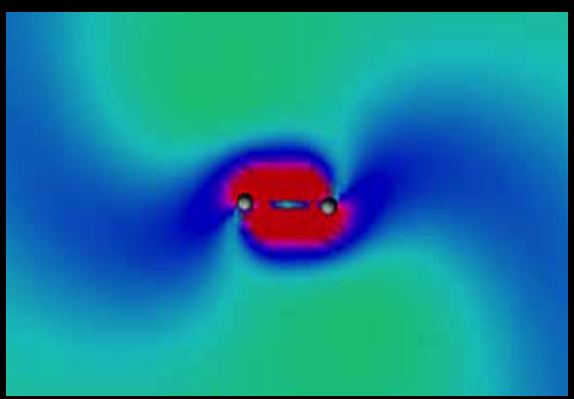
Wiggling a massive, compact object like a black hole creates gravity waves so powerful they can be detected across astronomical distances.

How black holes merge in a supercomputer

To recreate the merger of two black holes, numerical relativity researchers translate the equations of Einstein's general theory into a form a computer can understand and process. As the black holes circle each other, getting closer and closer, the computer model calculates their effect on local space-time. All images: Hans-Peter Bischoff/Center for Computational Relativity and Gravitation/Rochester Institute of Technology

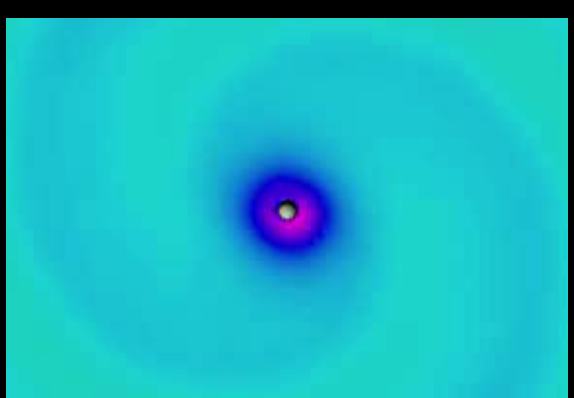


1 At this point, the black holes are still far apart. As a result, the disturbance in the "fabric" of local space-time is minor. To merge, they will have to tighten their mutual orbits by shedding energy. This is the beginning of the "inspiral" phase of the merger.



2 As the black holes get closer, the interaction of their massive gravitational fields intensifies. The wing-like, blue patterns at left and right indicate increasing disturbances in space-time called gravitational waves. They remove energy released during the merger process.

3 The black holes have merged and the disturbance to space-time is at maximum. The spiral pattern means gravitational waves are radiating in all directions, carrying away energy shed by the black holes in their merger process.



4 A single black hole is born in the merger. Now, in the "ringdown" phase of the process, the black hole vibrates for a period of time as the system settles back into a stable state. The overall disturbance to space-time is minimal.

either cut the black holes out of the grid in a process called excising, or you can try and slow the evolution down near the hole and then insert a solution you already know, which is called puncture," explains physicist Manuela Campanelli, director of the Center for Computational Relativity and Gravitation at the Rochester Institute of Technology (RIT) in New York.

Each choice has its problems, and neither worked well. The difficulties of computational relativity brought the field to a standstill. Only a few years ago, the situation appeared to be getting desperate. "The codes just crashed and crashed and crashed," Centrella says. "You couldn't even get an entire orbit out of them."

The inherent mathematical nastiness of general relativity's equations and the sheer difficulty of translating them into computer code rendered the models wildly unstable. Just a few steps into a calculation, the machines locked up by trying to divide by zero or some other impossibility.

Campanelli remembers it as a dark time. "People had really lost hope," she says. "These were scientists who had spent years building their codes. All that work, all that mathematics. No one wanted to toss it away and start again."

Then, in the midst of the melancholy, everything changed. It was a day that numerical relativists are not likely to forget for a long time.

The lone gunman

On April 19, 2005, numerical relativists gathered at a conference center in the mountains of Banff, Alberta. Frans Pretorius, a professor of physics at Princeton University, showed up with a secret. "Frans was the classic lone gunman," Hughes says. "He appeared at a conference and said 'Watch this.'"

After describing the mathematical background of his numerical code, Pretorius showed the audience a simulation with five full orbits of a black-hole pair. "It was just amazing," Hughes says. "Frans had solved it. He got it to work. It was like everybody was climbing this mountain only to find Frans on top already waving down at them."

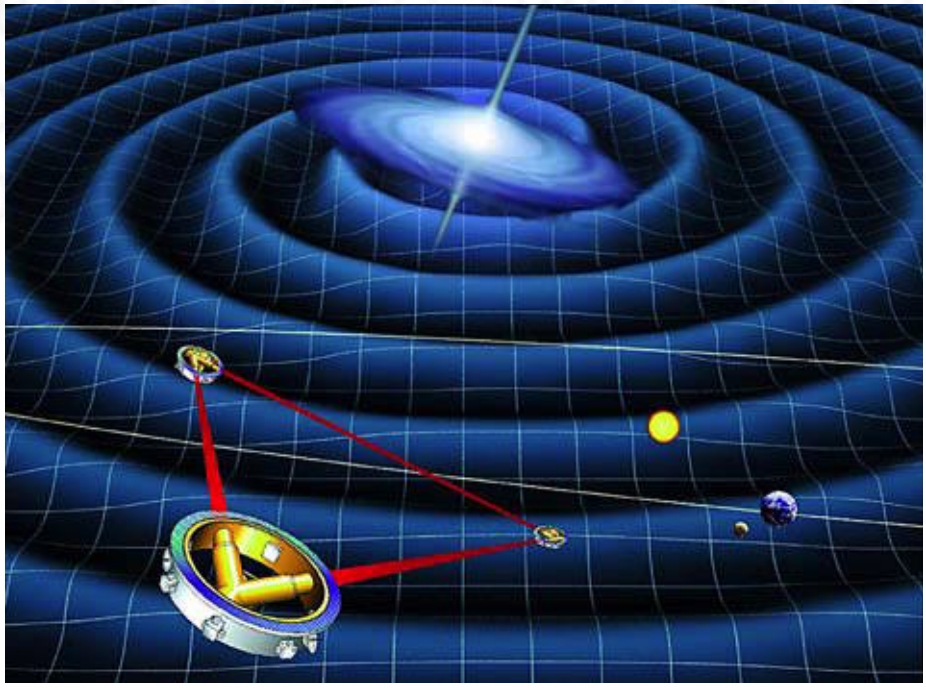
In Pretorius' new method, Einstein's equations take on a form similar to those describing simple waves. It was a highly

abstract, nonintuitive approach. But progress was not immediate. "My first attempt failed," he recalls. "In the second attempt, things were a little better."

News of Pretorius' achievement had leaked out before his talk. The buzz had already started when he arrived at the conference hall. "People were text messaging during my talk," he recalls. "Some guy set up with a video camera on a tripod and aimed it right at me. It was kind of embarrassing."

After Pretorius showed his animations and finished his talk, the community tried to digest what it had just seen. A few people were hostile. "There was a lot of investment in the methods researchers had been working with," Pretorius says. "Not everyone was pleased that I had come at it in an entirely different way and succeeded."

But most of Pretorius colleagues were thrilled. He had proved that numerical relativity was not an impossible dream. What happened next was more than anyone could have expected.



An orbiting gravity observatory called the Laser Interferometer Space Antenna (LISA) will detect passing ripples in space-time. LISA consists of three satellites orbiting in a triangular configuration. The satellites can compare measurements with each other via laser beams. NASA

Changing course

In the wake of Pretorius' success, all of the researchers asked themselves the same question. "If Frans got it to work his way," Centrella explains, "then did we all need to change to Frans' method?" Some researchers decided to press ahead with their existing codes.

The RIT group members decided to focus efforts on their puncture method for treating moving black holes. It had been a major source of problems for them, but they came up with a solution.

Many in the field of numerical relativity believed that a puncture representing a black hole could not move. So researchers would just pin the puncture in the grid and let space-time move around it.

Campanelli and her colleagues decided to allow the puncture to move. To everyone's surprise, the method produced spectacular results. Suddenly, Campanelli's group could track orbiting black holes all the way to merger.

The group presented the new success at the next numerical relativity meeting, but met with disbelief. "People saw our simulations but didn't understand how you could move the black hole across the grid," Campanelli says.

It might have gone worse for Campanelli's group if Joan Centrella's team hadn't shown up with simulations that used the same method. "The community was just stunned silent," Centrella recalls.

The simulation of black-hole mergers, from inspiral to ringdown, are now routine. "Now there are sessions at the American Astronomical Society meetings dedicated entirely to mergers," Centrella says. "And just a little while ago, we could not even get an orbit."

> "Frans was the classic lone gunman. He appeared at a conference and said 'Watch this.'" — Scott Hughes

Black holes, bright future

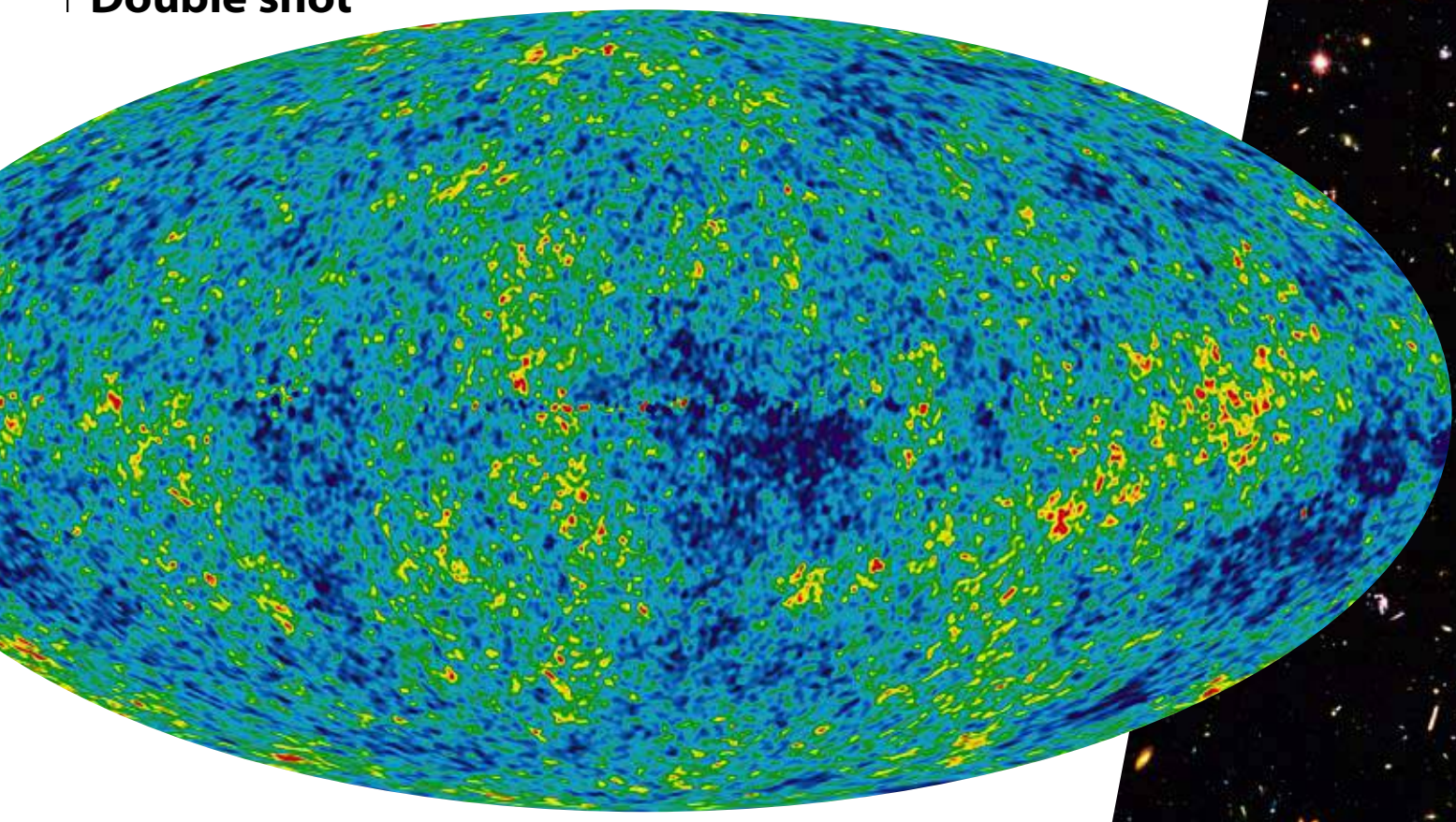
Researchers are moving quickly to explore additional black-hole merger scenarios, including mergers of black holes of different size and spin. "It's a feeding frenzy right now," Pretorius says. "And it will still take a few years until all the important cases have been mapped out."

Already, new surprises have appeared. Research with computer models shows that after a merger, the new, combined black hole experiences a powerful recoil force. In simulations, black holes blast away after mergers at speeds topping 625 miles (1,000 km) per second.

Simulated black-hole mergers can now provide guidance to LIGO and other gravity-wave observatories around the world. Sometime around 2013, LIGO will be upgraded to a more sensitive design, called Advanced LIGO. The improvements in sensitivity should finally give astronomers a telescope ready to detect black-hole mergers.

It has been a long, hard climb for LIGO Observatory scientists as they ready their detectors to hear passing gravitational waves. Numerical relativists experienced their own hard climb, and they are finally getting some satisfaction. They will be ready and waiting as LIGO turns its ear to the sky to detect the faint ripples of distant cataclysms.

Numerical relativity researcher Manuela Campanelli narrates an animation of a black-hole merger's final moments at www.Astronomy.com/toc.



Europe's SPACE REV

Two simultaneous European space missions will explore the cosmic background radiation and the structure that evolved from it. **by Bruce Dorminey**

The cosmic microwave background (CMB, above left) originated 380,000 years after the Big Bang, and shows traces of the earliest cosmic structures. The Planck mission will view the CMB with 10 times the sensitivity and three times the resolution of this WMAP image. NASA/WMAP Science Team

The Hubble Ultra Deep Field (above) provided the deepest view of the cosmos ever seen in visible light. The Herschel and Planck missions will see even farther at longer wavelengths. NASA/ESA/S. Beckwith (STScI)/The HUDF Team

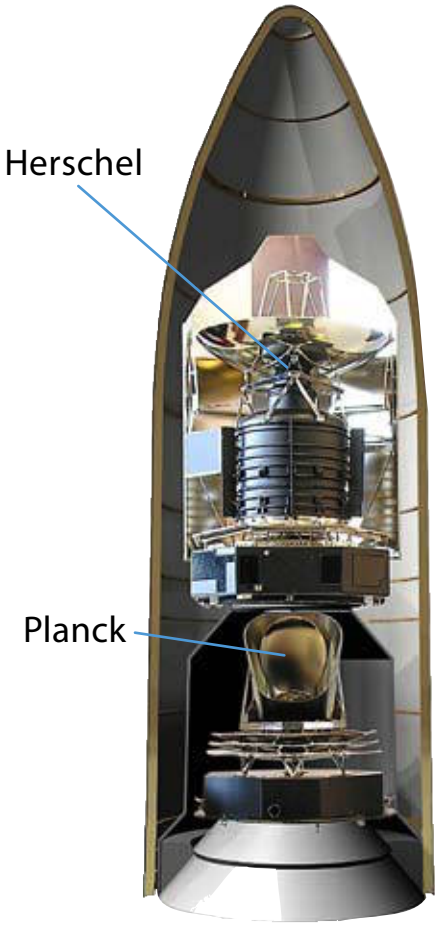
VOLUTION

Understanding cosmic history is a bit like walking backward — it's tricky on the best of days. But day in and day out, cosmologists attempt to retrace our steps back through time. The key question is: How much farther can they go?

This summer, the European Space Agency (ESA) hopes to find some fresh answers. With the joint launch of the $1.7 billion (1.1 billion euros) Herschel and Planck space missions, scientists will be able to probe the ultra-cool universe with unprecedented precision and sensitivity. Herschel and Planck will observe the cosmos at millimeter, submillimeter, and far-infrared wavelengths following their launch atop an Ariane 5 ECA rocket from Kourou, French Guiana, currently scheduled for late July.

With its 3.5-meter segmented primary mirror, the Herschel Space Observatory will be the largest space telescope ever. It will spend much of its time tracing galaxy evolution near the dawn of time. Yet, astronomers also anticipate its high-resolution spectral analysis of comets, protostars, circumstellar disks, and the interstellar medium.

Planck's main focus will be on surveying the structure of the cosmic microwave background (CMB), the relic radiation left over from the universe's genesis, the Big Bang. Cosmologists have anticipated Planck's detailed surveys for years. The spacecraft also will study the cool dust



Herschel (top) and Planck (bottom) will ride into space together atop an Ariane rocket. They will separate soon after launch and take different routes to their ultimate destinations at Sun-Earth L2. ESA/Guarniero

around quasars and in radio galaxies, star-forming regions, and within massive clusters of galaxies.

Astronomers hope these spacecraft will offer at least partial solutions to such cosmic puzzles as when the first stars formed and how density fluctuations in the CMB eventually evolved into the large-scale structure we observe today.

Two for the price of one

Coordinating two huge missions for launch on one rocket posed a daunting managerial challenge. Mission planners configured the two spacecraft together to reduce their costs. If anything goes wrong, however, ESA risks losing two prize missions. "It's a very big program, maybe too big," says ESA Director of Science David Southwood. "I do wonder about the sheer scale of this mission."

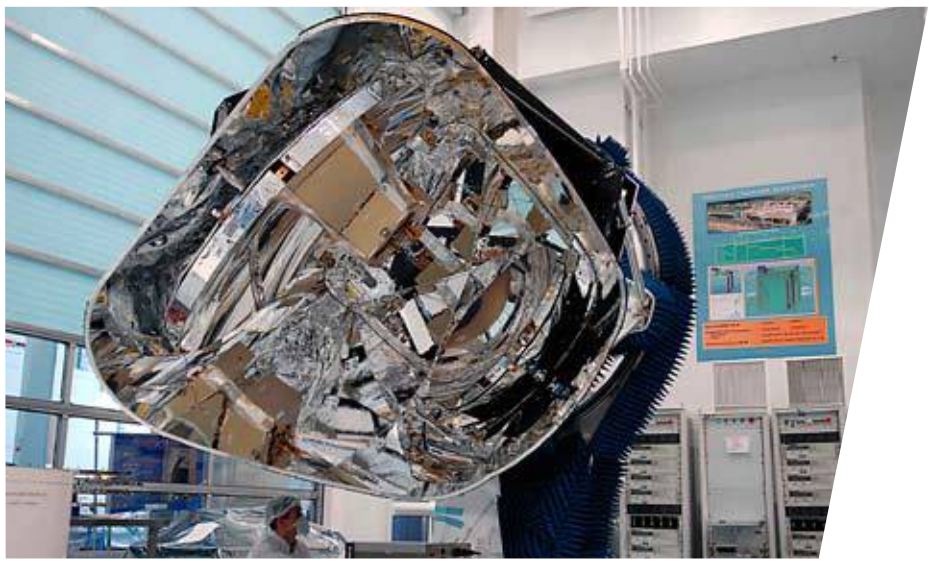
Risks aside, the scientific case for launching both missions as soon as possible proved compelling. Observing in a neglected part of the far-infrared spectrum blocked by Earth's atmosphere, Herschel will go well beyond NASA's Spitzer Space Telescope in both performance and sensitivity. And Planck will study the CMB with more than 10 times the sensitivity and 3 times better angular resolution than NASA's Wilkinson Microwave Anisotropy Probe (WMAP).

After launch, Herschel and Planck will take up their operational positions in orbit around Sun-Earth L2, a point of gravitational balance some 900,000 miles (1.5 million kilometers) from Earth. There, both spacecrafts' instruments will be cryogenically cooled to temperatures near absolute zero and continually pointed in a direction exactly opposite the Sun and Earth. Herschel's nominal mission spans 3.5 years, while Planck's lasts 2 years.

"It's a coincidence that Planck can act as a source identifier for Herschel even though the two missions are scientifically independent," says Southwood. "Planck's main task is to look at the CMB, but sources of interference in Planck's foreground will be grist for Herschel's mill."

With its 1.5-meter telescope and an array of detectors operating at both high and low frequencies, Planck will convert incoming microwave signals into units of temperature. For more than 40 years, the CMB has been arguably the most important source of information helping cosmologists understand the geometry and contents of the universe. Planck will survey the CMB at nine frequencies, collecting data that will allow scientists to map CMB temperature fluctuations as a function of its amplitude variations. The goal is to process and combine all nine frequency data sets to create a single overarching map of the CMB.

Herschel's 3.5-meter mirror will make it the largest telescope ever sent into space. Herschel will study cool parts of the universe at far-infrared wavelengths. Astrium/P. Dumas



The Planck spacecraft posed for its portrait in Cannes, France, in February 2007. Alcatel Alenia Space built the probe, which will observe the cosmic background radiation during a 2-year mission. ESA/S. Corvaja

Bruce Dorminey *is the author of* Distant Wanderers: The Search for Planets Beyond the Solar System *(Copernicus Books, 2001). His most recent* Astronomy *article was "Did molecules from space seed life in the cosmos?" in April 2008.*

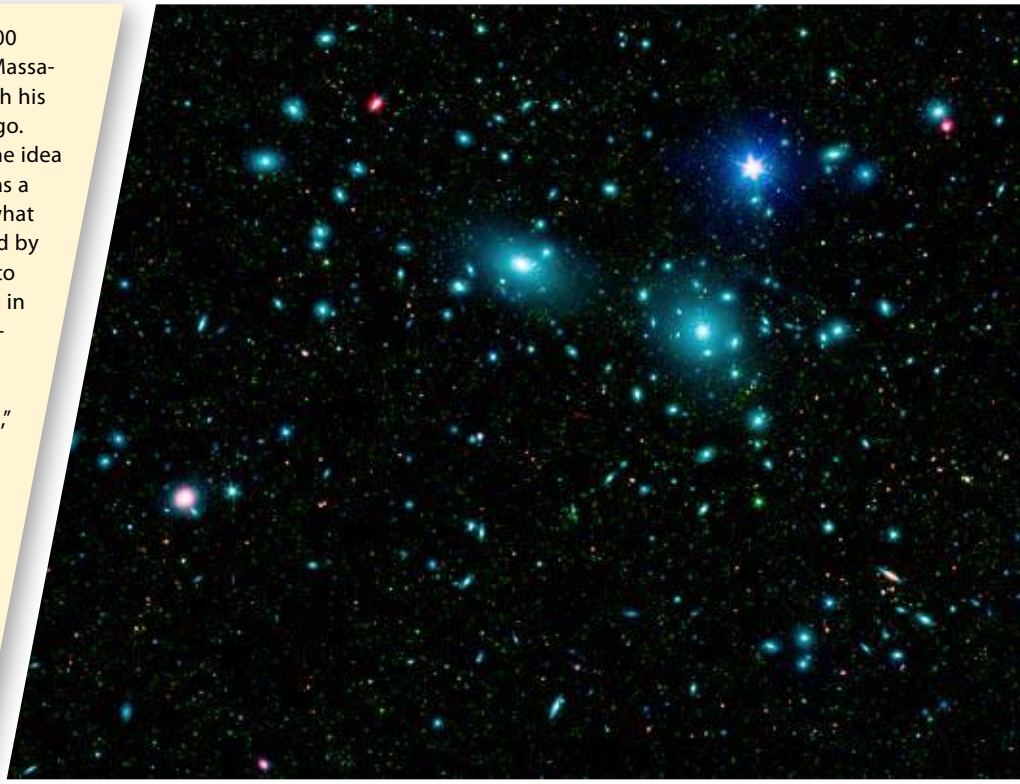
Inflation's guru

What spawned inflation? That's still the $64,000 question, says cosmologist Alan Guth of the Massachusetts Institute of Technology, who put forth his famous inflation theory more than 25 years ago.

"In my own mind," says Guth, "I still have the idea that the universe materialized from nothing, as a quantum fluctuation of some sort. Traces of what happened in the very early periods get diluted by this huge expansion. But all one really needs to start inflation is to have some probability that in some places, this initial state contains extraordinarily high energy densities; then, rather general initial conditions start inflation.

"According to almost all versions of inflation," Guth continues, "once it starts, it becomes eternal. With eternal inflation, you really do have an exponentially expanding region. Pieces of it break off and become pocket universes. Each pocket universe is on average much larger in size than what we observe in our universe. And if there's any probability of this starting, you get to produce an infinite number of universes, not just one."

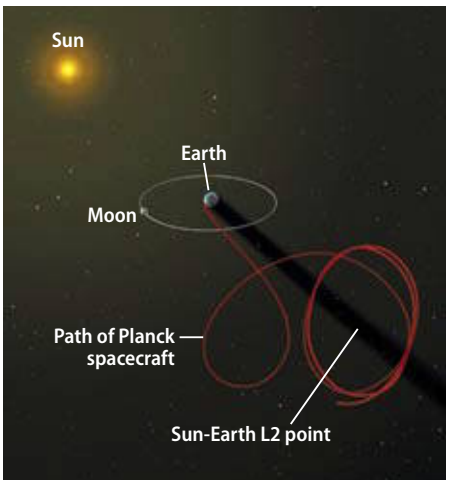
If Guth is correct, we're living in our own personal pocket universe. — *B. D.*



The rich Coma cluster of galaxies lies a relatively close 320 million light-years from Earth. Planck and Herschel will find and observe such massive clusters in the farthest reaches of the cosmos to learn how large-scale structure formed. NASA/JPL-Caltech/L. Jenkins (GSFC)

"Planck will make 10 times as many measurements with good signal-to-noise ratios as WMAP," says Charles Lawrence, an observational cosmologist at NASA's Jet Propulsion Laboratory and Project Scientist for the U.S. Planck Project. "So, the discovery space is pretty large."

Cosmologists think CMB density fluctuations were generated within 10^{-35} second of the Big Bang. They caused differences in CMB temperatures of just 1/1,000 of one percent. The tiny differences (or anisotropies) should harbor a signal that would offer incontrovertible proof of the theory of inflation. This "smoking gun" would be the direct detection of the amplitudes of so-called large-angular-scale B-mode polarizations in the CMB. Planck was not specifically designed to detect such B-mode polarizations, so many cosmologists remain skeptical that the signals will show up in the data.



Planck's long, looping path (red) after it separates from the Ariane launch vehicle will carry it beyond the Moon to its final orbit around Sun-Earth L2, a point some 900,000 miles (1.5 million km) from Earth. Herschel will take a separate but similar path to L2. ESA/C. Carreau

The epoch of inflation

MIT cosmologist Alan Guth put forth the first theory of cosmic inflation more than 25 years ago. It answered several nagging concerns by invoking a faster-than-light expansion of the nascent cosmos within a fraction of a second after the Big Bang.

"The only direct observation that puts constraints on when and on what energy scale inflation happened would be a measurement of gravitational radiation produced by inflation," says Guth. "This would show up in the polarization effects such gravity waves would have on the cosmic background radiation. It is possible that Planck will see those, and it would be incredibly exciting."

Detecting B-modes would immediately rule out the recently proposed "cyclic universe" cosmological model, which predicts B-modes so small as to be undetectable. If Planck doesn't see these modes, then inflation advocates, including Guth, admittedly will blame it on Planck and its inadequate observational sensitivity. That's because, Guth says, he simply can't imagine any viable alternative to inflation.

While cosmologists continue to debate the mechanics of the early cosmos, results from previous CMB missions give researchers confidence about at least a few points. When the cosmos was some 380,000 years old, at a redshift of about 1,100, photons decoupled from baryons (the stuff that makes up ordinary matter). This so-called recombination epoch occurs once the universe cools enough for protons to combine with electrons to make neutral hydrogen. The cosmos goes from being ionized to being neutral, and radiation travels unimpeded. This marks the birth of the CMB.

Spiral galaxies like M81 developed over billions of years, through a feedback process that helps regulate star formation. By observing distant galaxies, Herschel should shed some light on this poorly understood process. Hubble: NASA/ESA/A. Zezas (CfA); GALEX: NASA/JPL-Caltech/GALEX Team/J. Huchra, et al. (CfA); Spitzer: NASA/JPL/Caltech/S. Willner (CfA)

"From the first million years to 100 million years, no stars are forming, nothing is shining," says Daniel Eisenstein, a theoretical cosmologist at the University of Arizona. "That is the Dark Ages. Then, the first stars come in and after a few hundred million years of those stars burning away, you actually begin to ionize enough of the universe to produce a 10-percent-opaque screen. That's reionization."

Planck will give cosmologists a better idea of when the first stars formed. Current estimates on formation times for these so-called Population III (Pop III) stars, which astronomers think weighed more than 100 times as much as our Sun, range from about 100 million to 400 million years after the Big Bang. The ultraviolet radiation from these stars was crucial to reionizing the universe.

"With the future James Webb Space Telescope," says Eisenstein, "we will start to see some early galaxies. But these epochs are so remote, we won't be able to see the very first stars. CMB observations are a coarse tool, but one of the few tools we have now to infer what's really going on at these early epochs."

"With Planck, we will be able to tell the difference between a sudden reionization or a gradual reionization," continues Lawrence. "Imagine reionization starts around Pop III stars and then spreads. How many millions of years does that take?

"For a while, reionization might make the early universe look like Swiss cheese, with some parts that are transparent and some that are opaque. It's impossible to imagine that it happened all at once. WMAP couldn't tell us that it didn't. Planck will be able to."

From stars to galaxies

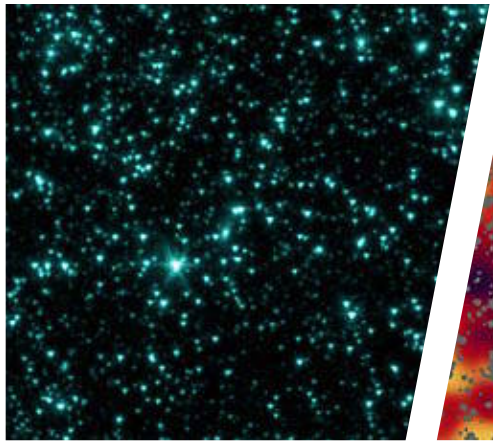
Perhaps most importantly, CMB observations also can give us an inkling of how the universe's large-scale structure arose. From WMAP observations, we know the first galaxies may have formed as early as 400 million years after the Big Bang.

But large-scale structure already is imprinted on the CMB, a relic from 380,000 years after cosmic genesis. Temperature fluctuations in the CMB reveal density fluctuations. And density peaks eventually evolved into galaxy superclusters. So, the seeds of large-scale structure represent a top-down construction, where smaller structures arose from bigger ones. That's in contrast to a bottom-up scenario, where large structures were built from individual galaxies.

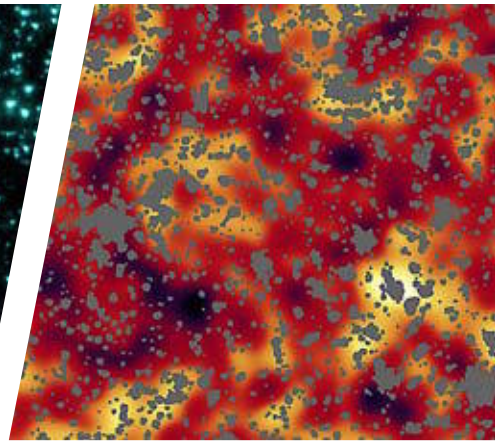
"There's no question," says Lawrence. "Large-scale structure is not formed bottom-up." Why? "There's not enough time," he explains.

On smaller scales, however, galaxies do form bottom-up. "The basic idea that galaxies build up their mass over time via mergers and accretion has to be right at some level," says Mark Dickinson, an observational astronomer at the National Optical Astronomy Observatory in Tucson. "But that doesn't mean we understand how it actually happens."

Galactic "feedback" plays a key role in how galaxies evolve over cosmic time. Astronomers think the energetic output from active galactic nuclei, massive black



Stars and galaxies populate this part of Ursa Major, shown here in a Spitzer Space Telescope infrared image. The view spans approximately 100 million light-years. NASA/JPL-Caltech/A. Kashlinsky (GSFC)



Background light shines through in this image, derived from the one at left by subtracting out stars, galaxies, and other known sources. What's left is radiation from the universe's first billion years — the first light following the Dark Ages. NASA/JPL-Caltech/A. Kashlinsky (GSFC)

holes, supernovae, and stellar winds all may generate feedback, which then regulates subsequent star formation. Today, says Dickinson, we see lots of galaxies that aren't forming stars. And, in fact, many massive galaxies stopped forming stars long ago.

So, in a general way, cosmologists understand the correlation between the seeds of matter — most of it dark matter — seen in the CMB density fluctuations and how such matter begins to form the earliest structures. What researchers don't understand well is how the feedback process causes young, distant galaxies to evolve into the grand spirals and other galaxies that dominate today's universe.

Still, galaxy modelers factor feedback assumptions into their numerical simulations. Such assumptions are particularly difficult to come by when astronomers have yet to study feedback observationally in high-redshift, distant galaxies.

Stellar nursery **DR 21** **hides behind a shroud of dust in Cygnus. NASA's Spitzer Space Telescope peered beyond this veil to reveal glowing gas and nascent stars. With its more powerful optics, Herschel will show star-forming regions in even greater detail.** NASA/JPL-Caltech/A. Marston (ESTEC/ESA)

Enter Herschel

"Herschel will help us understand how feedback works," says Caltech astronomer Phil Appleton at NASA's Herschel Science Center. "One of the challenges of the next decade is to understand how galaxies assemble over cosmic time. There is a connection between seed perturbations in the CMB and what we see when galaxies start to assemble around dark-matter halos. But how baryonic matter is assembled within those dark-matter halos is very unclear at this stage."

Planck will identify some 10,000 to 20,000 massive galaxy clusters via an astrophysical effect first theorized by two Soviet physicists in 1969. Known as the Sunyaev-Zeldovich Effect (SZE), it describes how CMB photons get kicked up to higher energies when they pass through free electrons in the hot, ionized gas inside massive galaxy clusters. This effect distorts the appearance of the background CMB.

Because these galaxy clusters possess so much mass, Planck should be able to detect them via these SZE distortions. A single galaxy, however, would never have enough mass to cause such distortions in the CMB. "If you heat up Earth's atmosphere to a million degrees," says Lawrence, "that gas just goes off into space. So, it takes a really serious bunch of gravity to hold in this cloud of hot, ionized gas at millions of degrees."

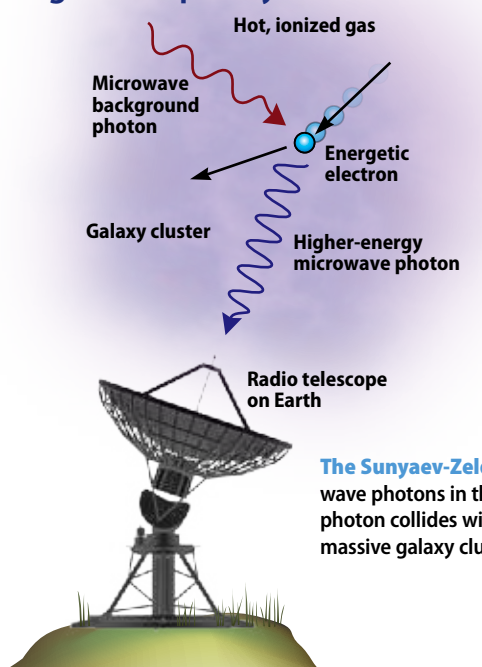
Lawrence says the difficulty in applying the SZE comes in making observations with a resolution high enough to get the details of what's going on in the cluster. Planck will find the clusters. To glean significant detail on them, though, will require follow-up observations by both Herschel and current and future space-based X-ray telescopes.

"One of the big problems in cosmology is that there are galaxy clusters which emit most of their energy in the far-infrared [far-IR] part of the spectrum," says Goran Pilbratt, ESA Herschel Project Scientist. "In the far IR, we see emission from dust. If you don't observe in this range, your picture of how galaxies evolve becomes severely skewed. Herschel can see the peak of the emission and determine these clusters' true luminosities."

But, as Dickinson notes, most of the energy from star formation at high redshift is absorbed by dust and reradiated in the far IR. That far-IR emission subsequently gets redshifted even further into the infrared. "So you have to look in the far IR to see most of the energy coming out from these distant galaxies," Dickinson explains. "That's what we really haven't observed before. Herschel will help a lot at these far-IR wavelengths."

As Southwood sees it, cosmology stands at a turning point. "Is there something that will come out of a more detailed structure of the CMB that could really throw new light on the limits of the standard model?" he asks. "Both missions are likely to make big headlines in cosmology. But we do these things because we're exploring the unknown. If I could tell you what we were going to find, I shouldn't take the money in the first place."

Changing light's frequency



The Sunyaev-Zeldovich Effect **gives a slight energy boost to microwave photons in the cosmic background. The kick comes when the photon collides with an energetic electron in the ionized gas of a massive galaxy cluster.** *Astronomy*: Roen Kelly

THE COMING SOLAR SUP

In 1859, the Sun unleashed its biggest storm in 450 years. We're more

Hot plasma arcs above a sunspot over the Sun's limb. The ultraviolet scene, captured in late 2006, reveals fine-scale structure extending from the mottling, or granulation, on the Sun's surface and into its lower atmosphere. Hinode, the most advanced solar telescope ever flown in space, launched September 22, 2006, and returned this view.

JAXA/NASA/Hinode

Any disaster capable of causing large-scale blackouts, disrupting communications networks, and damaging satellites is something to prepare for. These are just a few of the effects that follow powerful eruptions from the Sun.

Scientists now recognize that we haven't seen the worst the Sun can throw at us. Solar flares in 1859 kicked off a storm so massive that, if it happened today, could cripple much of the technology we've come to rely on.

vulnerable than ever to its next blast. **by Sten Odenwald**

PERSTORM

Solar cycles

The Sun's storminess rises and falls every 11 years, on average. Cycle 23 is now drawing to a close. Since 1996, this cycle has produced more than 21,000 flares — giant magnetic explosions on the Sun's surface. It has launched 13,000 coronal mass ejections (CMEs) — billion-ton clouds of ionized gas (plasma) that race through interplanetary space.

Both events can trigger spectacular auroral displays (the so-called northern and southern lights). But the same radiation that produces these beautiful glows can damage satellite electronics. Radiation from solar flares also can ionize the atmosphere so strongly that radio communication at some frequencies is impossible for hours. Electrical currents flowing at the top of the atmosphere can induce currents on the ground in long conductors, like the national power grid, and damage and destroy transformers and other equipment.

As solar cycles go, Cycle 23 was well behaved. Its worst blasts, which included a record-breaking flare November 4, 2003, spawned intense activity now known in space-weather circles as the Halloween Storms. They crippled instruments on some spacecraft, including NASA's Mars Odyssey, and triggered a blackout in Sweden.

But that, researchers say, was nothing. Once every few centuries, the Sun erupts with an event unlike anything modern scientists have ever experienced.

The 1859 superstorm

Between August 28 and September 6, 1859, the Sun produced one of its most spectacular solar storms in the last 450 years. Scientists who reconstructed this event from historical data put it in a class by itself. They call it a superstorm. Here's what it was like.

The first CME arrived at 7h30m Universal Time (UT) August 28, 1859. Dozens of instruments around the world recorded its passage as a minor magnetic glitch. Yet, even by modern standards, this was a major storm.

Normally, a storm's north-directed magnetic field squelches any auroral displays. But despite its incorrect magnetic orientation, the 1859 storm was so intense it spawned aurorae seen as far south as Athens, Greece. Why? Some hours before the bubble of hot gas reached Earth, it emitted a gale of fast-moving protons. These particles raced ahead of the cloud and were absorbed by Earth's atmosphere. These particles, not the CME itself, produced the light show.

A few days later, a second CME raced past our planet. British astronomers Richard Carrington and Richard Hodgson, who happened to be observing the Sun, witnessed the launch of this massive cloud by a rare and powerful solar flare (see "Stars on the Sun," p. 36).

Stars on the Sun

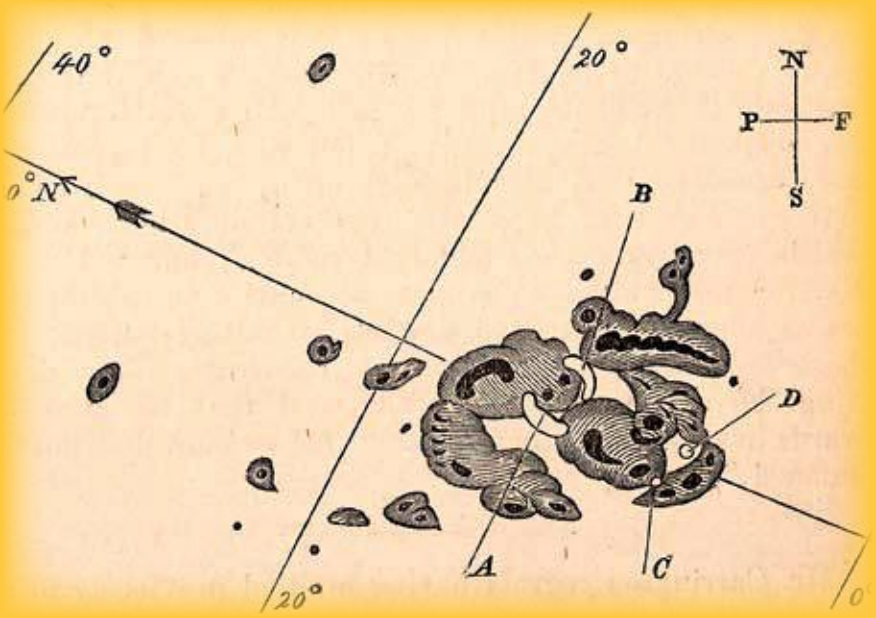
On September 1, 1859, two British astronomers independently observed a rare and powerful flare on the Sun's disk. It was this eruption that launched round two of the solar superstorm.

Richard Carrington and Richard Hodgson were observing sunspots by projecting the Sun's image onto a screen. Carrington had completed drawing sunspot groups when, at 11:18 A.M. Greenwich Mean Time, he noticed "two patches of intensely bright and white light" near the largest group.

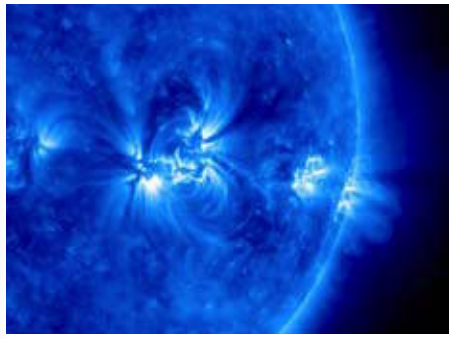
Hodgson described the flare as a "brilliant star of light, much brighter than the Sun's surface, and most dazzling to the protected eye." The show ended 5 minutes later.

In that time, Carrington noted, the patches of light moved some 35,000 miles (56,000 km) across the Sun's disk. He saw no changes to the spots themselves, and concluded that "the phenomenon took place at an elevation considerably above the general surface of the Sun."

What these observers couldn't see, of course, was the massive CME this flare launched toward Earth. But Carrington suggested the flare might be related to the exceptional magnetic storm that followed 17 hours later. — *Francis Reddy*



Richard Carrington sketched the massive white-light flare he witnessed September 1, 1859. The eruption began at the locations marked A and B. The eruption subsided 5 minutes later at points C and D. Linda Hall Library



Magnetic loops arch above solar active regions June 9, 2007. These areas of intense magnetism often are sources of solar storms. NASA/STEREO

This CME had everything going for it. It was fast: In just 17 hours, the cloud swept across the entire inner solar system at a speed of 5 million mph (8 million km/h). The dense wall of plasma also possessed a southward-pointing magnetic field, which enhanced its potential impact. At 4h40m UT September 2, part of this monster plasma cloud brushed past Earth.

Our planet resides in a protective bubble created by its magnetic field and ions trapped inside it. Within minutes of the cloud's impact, the entire Sun-facing hemisphere of Earth's magnetic bubble was compressed until it reached the outer atmosphere's fringes. The blow instantly affected the ozone layer, reducing this ultraviolet-absorbing gas so much — by about 5 percent — that it took years to recover to pre-storm levels.

The night-side portion of Earth's magnetic field became a complex, tangled web of field lines trying to sort themselves out within an enormous volume of space. This magnetic upheaval, invisible to the human eye, may have continued for more than a day.

From the ground, spectacular crimson aurorae could be seen as far south as equatorial Central America and Bombay, India. Predictably, people mistook the lights for distant cities on fire, or imagined them as specters dancing in glee over some celestial battle. They stood and gawked by the millions and wrote detailed eyewitness accounts to newspapers. Miners awoke after midnight and broke camp, thinking dawn had arrived. Thousands of people comfortably read newspapers under the night sky's wavering crimson glow.

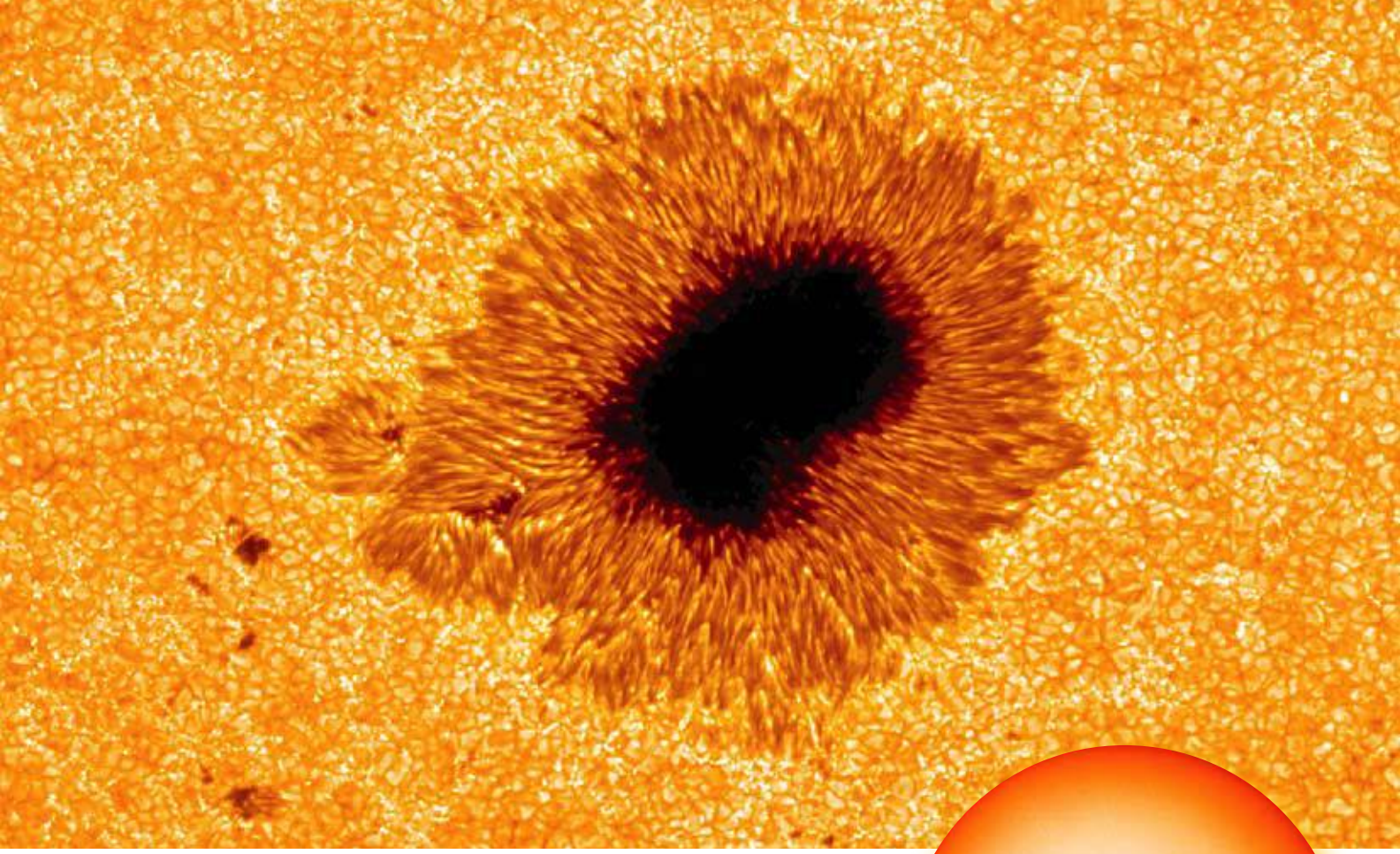
In this pre-Civil War era, telegraph outages and instrument fires proved to be the only technological impact. The currents generated underground by the storm's shifting magnetic and electric fields were so powerful they set fires in telegraph offices on both sides of the Atlantic. In Washington, D.C., they nearly electrocuted telegraph operator Frederick Royce.

Today, the calamity such a storm would cause would have no historical precedent. At no other time has the web of technology so completely engulfed our day-to-day lives. Billions of people are in close personal contact with the technologies most prone to space weather's effects. Luckily, superstorms seem to be rare events for a star like our Sun.

Deep freeze

Deep within ice crystals in Greenland and Antarctica, nitrate molecules have collected in trapped gases since 1561. Scientists Michael Smart, Donald Shea, and Kenneth McCracken at the U.S. Air Force Research Lab at Wright-Patterson Air Force Base, Ohio, and the University of Maryland discovered that nitrate concentrations rise and fall with solar activ-

Sten Odenwald *is a professor of astronomy at Catholic University in Washington. He is an avid science popularizer and author.*



This Hinode image provides the sharpest-ever look into a modest sunspot about 4 times Earth's size. Rising and falling cells of hot gas create the mottled appearance, called granulation, of the Sun's normal surface. Sunspots appear dark because their strong magnetic fields suppress rising columns of hot gas and allow the spots to cool. JAXA/NASA/Hinode

ity. Nitrates are a particularly good barometer of powerful radiation storms called solar proton events (SPEs). In the 450 years covered by the frozen record, the biggest SPE was the 1859 superstorm.

The satellite industry uses the storm event that occurred August 4, 1972, as its worst case. According to the nitrate record, 19 events more intense than this storm have occurred since 1561. In addition, they occurred, on average, in 23-year intervals.

The August 1972 event, which was one-fourth as strong as the superstorm, is the only one that even comes close to its power since 1965. In fact, during the last 4 decades, the Sun has produced the fewest large SPEs of any 40-year span back to 1670.

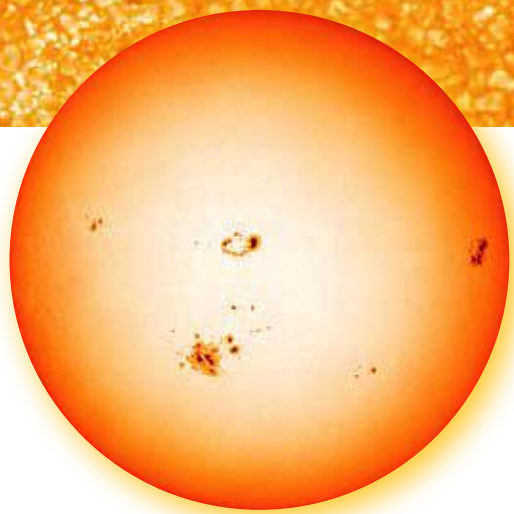
So, if you wanted to build satellites to endure the rigors of the space environment, the solar storms of the past 40 years' are the wrong examples to use. In truth, things can get much nastier than these storms indicate.

Scientists can't predict when one of these superstorms will occur. Here's what we can expect if Cycle 24 launches one our way.

The next superstorm

The superstorm likely would come sometime between 2010 and 2012, near the peak of the Sun's activity cycle. The most favorable months would be March or September,

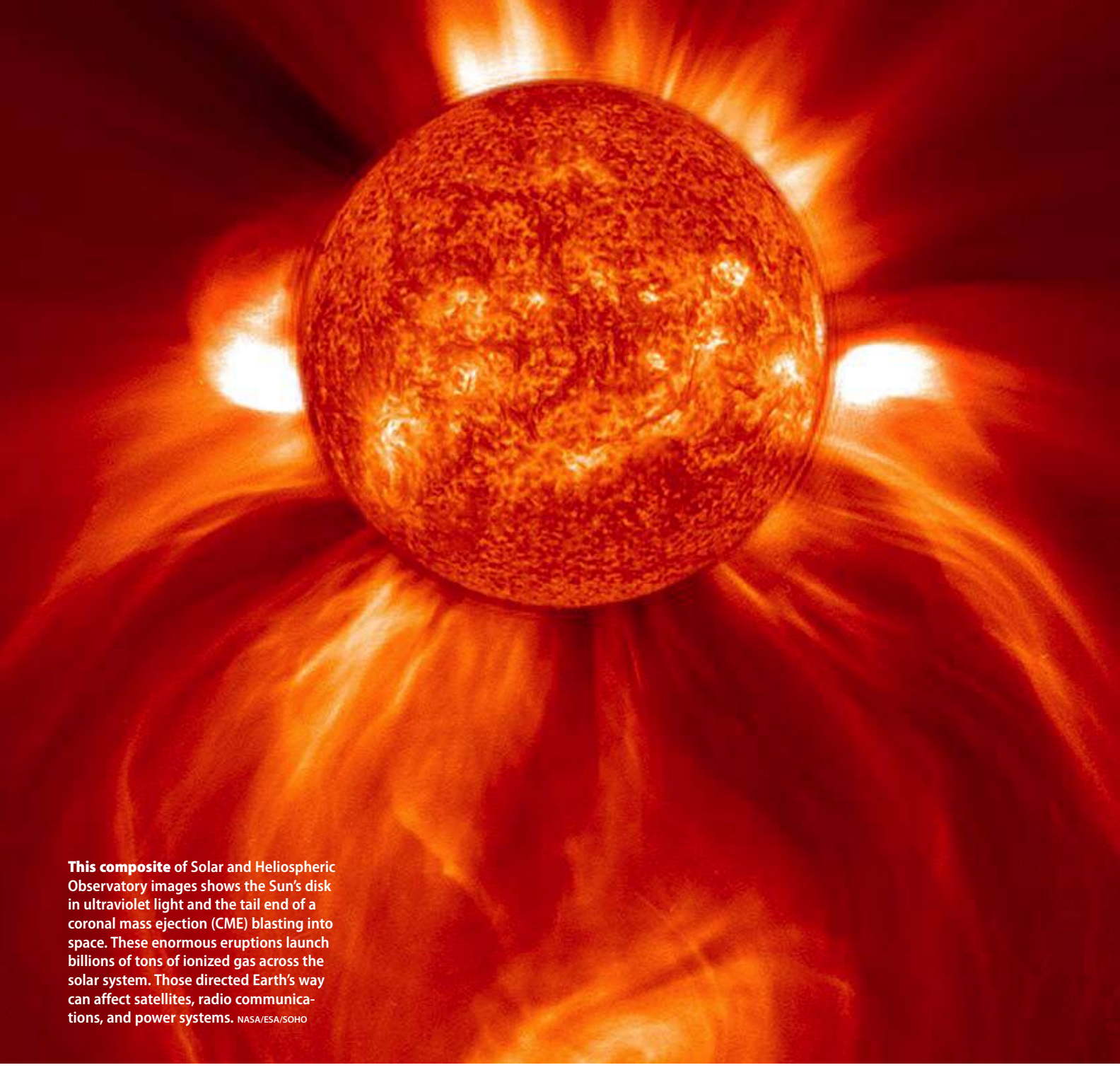
The August 1972 solar storm serves as the satellite industry's worst case, but the 1859 superstorm packed 4 times its punch.



Enormous sunspots more than 10 times Earth's diameter peppered the Sun in October 2003. These spots launched the record-breaking Halloween solar storms. NASA/ESA/SOHO

during the equinoxes, when solar storms can more easily impact Earth.

The first warning sign might be the presence of a large, distorted sunspot group. Scientists expect dozens of small X-ray flares (classed as X-1 and up) from such systems. They also can produce a few moderate-intensity (X-10 and up) flares. These occurrences signal highly disturbed magnetic conditions within the spot. Each flare would cause notable short-wave radio blackouts, but only amateur radio operators and some emergency services might take notice.



This composite of Solar and Heliospheric Observatory images shows the Sun's disk in ultraviolet light and the tail end of a coronal mass ejection (CME) blasting into space. These enormous eruptions launch billions of tons of ionized gas across the solar system. Those directed Earth's way can affect satellites, radio communications, and power systems. NASA/ESA/SOHO

Unless the sunspot group launched a white-light flare visible to lucky amateur and professional solar observers, the first to see the eruption would be an armada of aging solar research satellites, such as Hinode, STEREO, and the Solar Dynamics Observatory.

An intense blast of X rays and energetic particles would black out every sensor system in space on Earth's daylight side. The X-ray pulse also would destroy the atmosphere's ionized D-layer. This would instantly black out short-wave broadcasts across the hemisphere facing the Sun.

The entire Arctic region, perhaps extending to the Great Lakes, would experience a Polar Cap Absorption event, where a flood of solar protons knocks out most radio communications. This would be an instant hazard to air travel and lead to days of delays and costly flight rerouting.

As in 1859, the atmosphere would lose 5 or 10 percent of its ozone layer, which would raise skin cancer rates in the following years. And the night sky would blaze bright enough to confuse animals — and let humans read beneath eerie auroral glows.

If the superstorm arrived as a so-called double-barreled CME, the first would dazzle Northern Hemisphere sky-watchers with spectacular aurorae rivaling those produced by 2003's Halloween Storms. The second punch, launched perhaps a day later, would race through the inner solar system and arrive at Earth within 20 hours.

At impact, all geosynchronous satellites outside Earth's protective magnetic bubble would find themselves immersed in a turbulent magnetic plasma they weren't designed to endure for long. Accelerated by shock waves in the CME, a tremendous pulse of fast-moving protons would race ahead of the cloud and arrive 12 hours earlier. The radiation instantly would invade satellite circuitry. Satellite controllers would record thousands of glitches, some serious enough to end the hardware's operational life.

In a few hours, the effects on satellites alone could result in a loss of $20 billion in revenue and resources. U.S. Defense Department satellites also would be blinded by varying degrees. The Global Positioning System would report inaccurate positions for a day or more, impacting precision navigation, oil drilling, and some military operations.

As the proton storm's particles enter Earth's atmosphere, they would initiate nuclear reactions with oxygen and nitrogen atoms. The result would be showers of high-speed neutrons, many of which would reach the ground. Computer systems would crash as so-called "sudden event upsets" violate the integrity of binary information stored in memory.

The next superstorm's effects on satellites alone could reach $20 billion a day in lost revenue and resources.

Lucky break?

Despite this grim scenario, we might actually luck out. Half the time, a CME's magnetic field is oriented north, which minimizes its interaction with Earth's magnetic field. Such a storm would pass by with only moderate impact.

Then again, our luck could go the other way. According to John Kappenman, an electric power engineer at MetaTech Corporation in Goleta, California, a solar storm as severe as one that occurred in 1921 would affect all of North America in an unprecedented blackout. More than 150 million would lose electricity for days or even weeks. Insidious magnetic storm currents would damage transformers. Replacements would be hard to come by because no domestic suppliers exist.

A 2003 blackout in the northeastern United States involved 50 million people and 12 states and Canadian provinces, and cost $6 billion over a 24-hour period. During a superstorm event, such effects might linger for a week or more. The cost could exceed $20 billion a day in lost salaries, spoiled food, and other collateral effects.

Making headlines

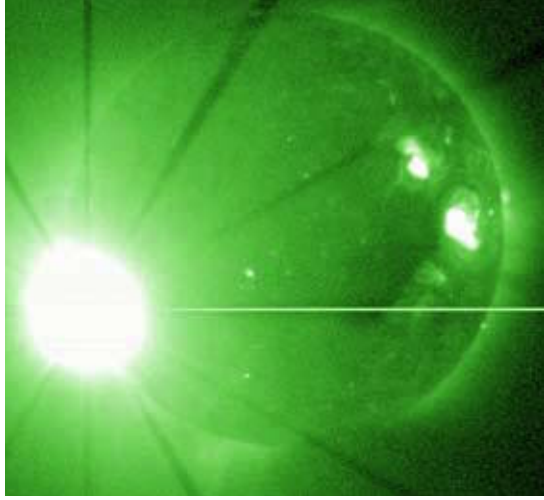
Newspaper accounts often described the last century's solar storms. On March 25, 1940, the *Boston Globe* ran the headline "U.S. Hit by Magnetic Storm" in 2-inch type above the fold.

Editors banked heavily on the average reader knowing what a magnetic storm was. Back then, many people did.

Since the 1950s, solar storms have all but vanished from the front page. Those that make it to print lack details of specific incidents, which mutes their human impact. For instance, the historic March 13, 1989, storm blacked out Quebec for 12 hours and cost several billion dollars. Yet this remarkable cosmic event was never mentioned in major U.S. papers.

It's ironic that we're now far more vulnerable to major solar storms. They now tend to be regarded by the public as entertainment and nighttime spectacle, rather than their historically demonstrated capacity to do serious harm. For instance, the solar storm of September 18, 1946, caused navigation errors that led to a famous plane crash in Gander, Newfoundland, which killed 26 passengers and crew.

The previous sunspot cycle — Cycle 22 — was quite eventful. It led to a costly period of satellite outages and losses totaling, by some estimates, nearly $3 billion. Satellite industry trade journals spoke about insurance brokers struggling under billion-dollar annual payouts. Collectively, commercial satellites lost about 3 years of their operational lifespan, which translates to tens of billions of dollars in lost profit. There also were several incidents with U.S. electrical power grids, some of which found themselves pushed to near-blackout conditions.



On December 5 and 6, 2006, as solar cycle 23 approached its activity minimum, two powerful X-ray flares exploded on the Sun's limb. The X-ray imager aboard the GOES 13 weather satellite captured this view of the first flare, rated X-9, and experienced slight damage during the event. NGDC/NOAA

Yet, over the past 5 years, the U.S. Congress has steadily reduced National Oceanic and Atmospheric Administration funding for maintaining and improving our space-weather forecasting ability. The $6 million annual budget pays for operation of the Space Weather Prediction Center in Boulder, Colorado. Its forecasts, which are used by thousands of companies and government agencies each year, save an estimated $200 million annually. If this doesn't seem like a bargain, factor in safeguarding the $500 billion in annual revenues generated by the power industry and satellite commerce.

Our next national blackout could come as a surprise, even though the technology needed to alert us was used during the previous solar cycle. If the cosmic dice fall the wrong way when the Sun's activity peaks again, we may well look back at Cycle 23 as the good old days.

See movies of the Sun from the Hinode solar observatory at www.astronomy.com/toc.

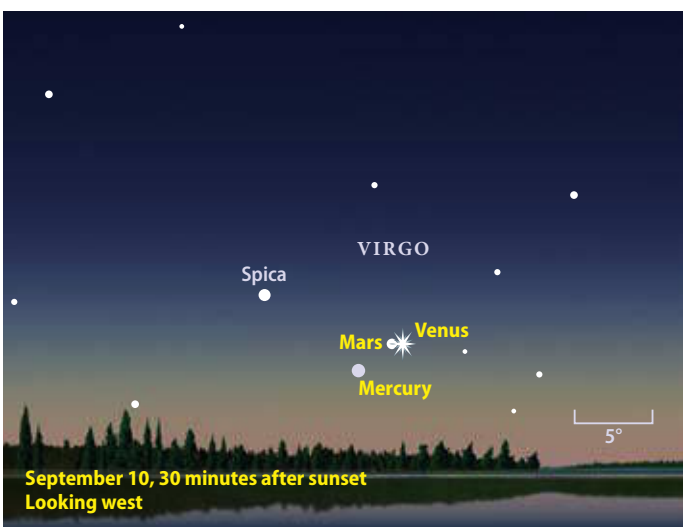
The sky this month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

September 08

Planets pierce the twilight

Brilliant Venus (near the horizon and right of the cactus) passed close to Mercury before dawn December 30, 2004. The two reprise their meeting after sunset this month. Joe Orman



Mercury, Venus, and Mars join with the bright star Spica to create an ever-changing tapestry these September evenings. *Astronomy*: Theo Cobb

While some planets come to the fore this month, others fade away. Both Mercury and Mars drop out of view, but not before they have a fascinating conjunction with Venus. Brilliant Venus serves as a beacon to find the fainter planets in bright twilight.

Jupiter remains a stunning sight in the southern sky all evening, while Uranus, an easy binocular object, reaches opposition and best visibility. As September closes, Saturn returns to the morning sky. You won't have a better chance to see its rapidly narrowing rings for several months.

The planetary action begins soon after sunset. **Venus** appears first in the deepening twilight. You should spot the brightest planet, which shines at magnitude –3.8 and hangs low in the west, within 30 minutes of sunset. Through a telescope, Venus shows a disk that spans 11" and appears 89-percent lit. You won't see much change in its apparent size or phase during September.

Although Venus' telescopic appearance stays nearly constant, its tango with Mercury and Mars will intrigue both naked-eye and binocular viewers. The dance plays out on a stage set against the backdrop of the constellation Virgo the Maiden.

Venus and Mercury begin September within 3° of each other. Mercury appears much dimmer, at magnitude 0.0, and binoculars will help you find it in the bright twilight.

The two move in step as they close in on **Mars**, which shines much fainter, at magnitude 1.7. The September 11 conjunction between Mars and Venus, when the planets stand just 0.3° apart, will be hard to see without binoculars from mid-northern latitudes. Observers farther south will have a better view of all three planets because they appear higher and remain above the horizon several minutes longer after sunset.

Mercury is somewhat easier to see than Mars because it shines significantly brighter. The innermost planet reaches greatest elongation September

— *Continued on page 45*

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46 Comet search
47 Spying asteroids
47 The Moon passes the Pleiades

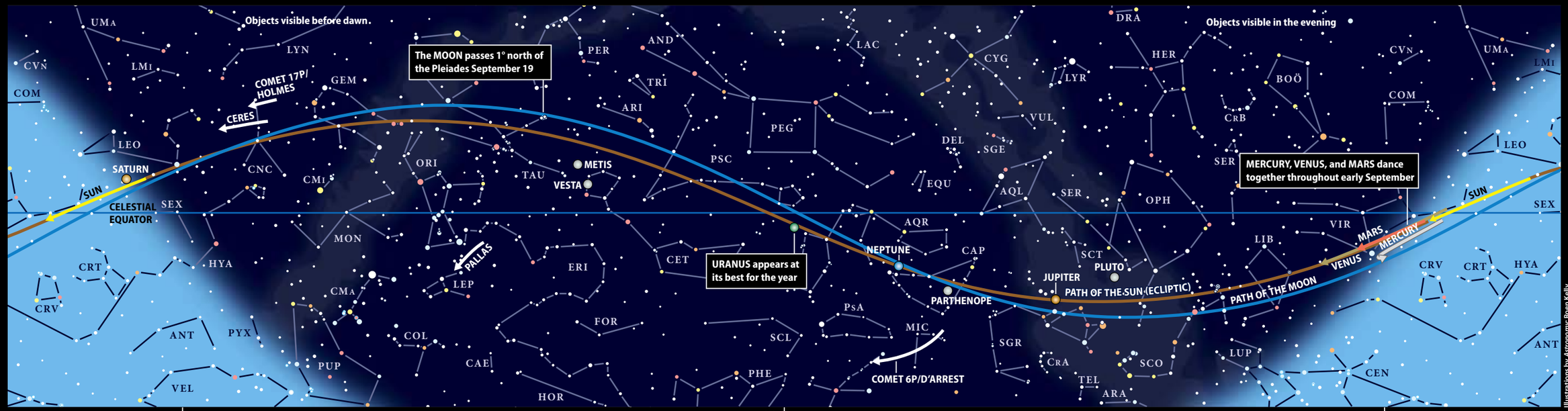
Visible to the naked eye
Visible with binoculars
Visible with a telescope

Planets in September 08

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets



Illustrations by *Astronomy*: Roen Kelly

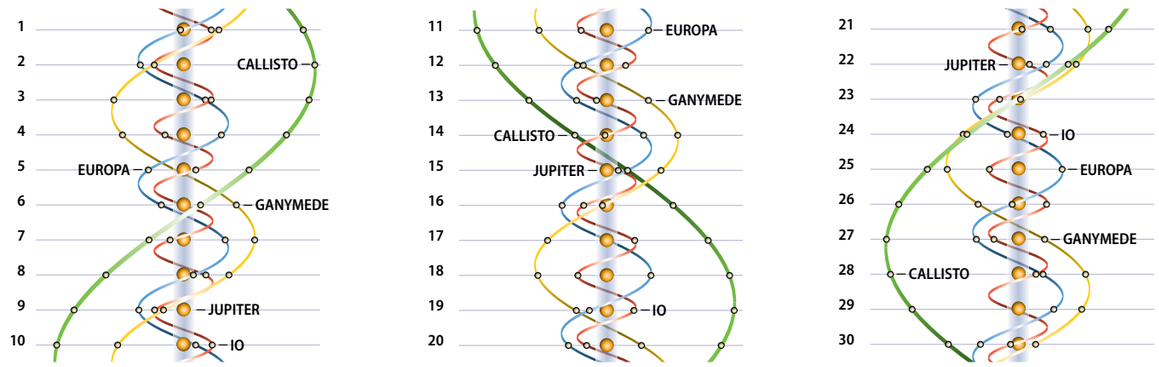
MOON PHASES

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown in 0h Universal Time.

PLANETS	MERCURY	MERCURY	VENUS	MARS	• CERES	JUPITER	SATURN	URANUS	NEPTUNE	• PLUTO
Date	September 1	September 15	September 15	September 15	September 15	September 15	September 30	September 15	September 15	September 15
Magnitude	0.0	0.2	–3.8	1.7	8.8	–2.4	1.0	5.7	7.8	14.0
Angular size	6.1"	7.5"	11.3"	3.8"	0.4"	41.8"	16.2"	3.7"	2.3"	0.1"
Illumination	70%	50%	89%	98%	98%	99%	100%	100%	100%	100%
Distance (AU) from Earth	1.103	0.898	1.472	2.450	3.247	4.721	10.261	19.093	29.166	31.402
Distance (AU) from Sun	0.466	0.449	0.725	1.593	2.585	5.153	9.341	20.098	30.037	31.522
Right ascension (2000.0)	12h12.1m	13h04.5m	13h10.0m	13h03.5m	8h59.2m	18h54.4m	11h07.5m	23h26.2m	21h37.7m	17h53.2m
Declination (2000.0)	–2°30'	–10°11'	–6°49'	–6°23'	22°14'	–23°10'	7°29'	–4°31'	–14°32	–17°22'

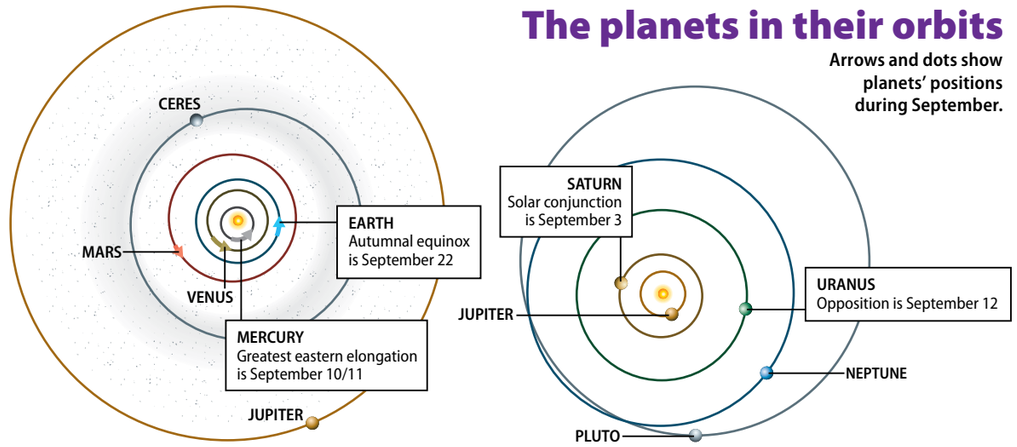
Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during September.



StarDome

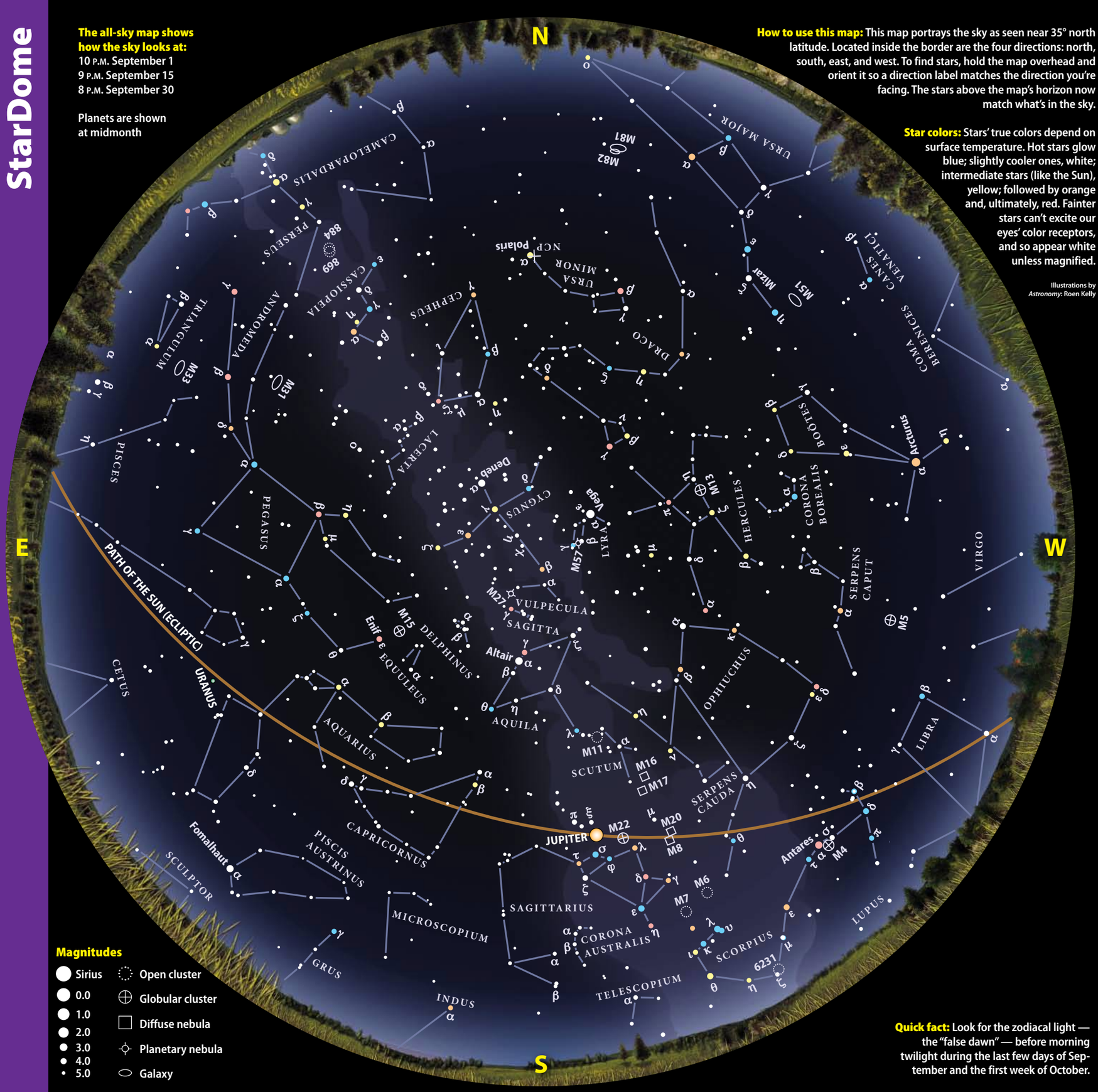
The all-sky map shows how the sky looks at:
10 P.M. September 1
9 P.M. September 15
8 P.M. September 30

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: Look for the zodiacal light — the "false dawn" — before morning twilight during the last few days of September and the first week of October.

September 08

Note: Moon phases in the calendar vary in size due to distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Calendar of events

1 The Moon passes 5° south of Venus, 5 P.M. EDT

The Moon passes 3° south of Mercury, 7 P.M. EDT

2 The Moon passes 5° south of Mars, 4 A.M. EDT

3 Saturn is in conjunction with the Sun, 10 P.M. EDT

6 The Moon passes 0.3° south of Antares, 11 P.M. EDT

7 First Quarter Moon occurs at 10:04 A.M. EDT

The Moon is at apogee (251,167 miles from Earth), 10:57 A.M. EDT

Jupiter is stationary, 11 P.M. EDT

9 The Moon passes 3° south of Jupiter, 4 P.M. EDT

10 Mercury is at greatest eastern elongation (27°), midnight EDT

11 Mercury passes 4° south of Venus, 1 A.M. EDT

Venus passes 0.3° north of Mars, 5 P.M. EDT

12 Mercury passes 3° south of Mars, 5 P.M. EDT

The Moon passes 0.8° north of Neptune, 10 P.M. EDT

Uranus is at opposition, 10 P.M. EDT

Special observing date

Sept. 12: Uranus reaches opposition and peak visibility.

15 The Moon passes 4° north of Uranus, 4 A.M. EDT

Full Moon occurs at 5:13 A.M. EDT

18 Venus passes 3° north of Spica, 5 A.M. EDT

19 Mercury passes 4° south of Mars, 1 A.M. EDT

The Moon is at perigee (229,215 miles from Earth), 11:27 P.M. EDT

The Moon passes 1° north of the Pleiades, midnight EDT

22 Last Quarter Moon occurs at 1:04 A.M. EDT

Autumnal equinox occurs at 11:44 A.M. EDT

23 Mars passes 2° north of Spica, 3 P.M. EDT

27 The Moon passes 5° south of Saturn, 4 P.M. EDT

29 New Moon occurs at 4:12 A.M. EDT

30 The Moon passes 5° south of Mars, midnight EDT

For definitions of terms, log onto www.Astronomy.com/glossary.

Astronomy magazine

— *Continued from page 40*

10/11. It then lies 27° east of the Sun, a larger elongation than normal because Mercury is traversing the part of its orbit farthest from our star.

Unfortunately, the planet's great distance from the Sun doesn't translate into much altitude. From the Northern Hemisphere, most of the separation runs parallel to the horizon, not perpendicular. On the evening of greatest elongation, Mercury lies 4° to Venus' lower left.

A week later, on September 18, Venus passes 3° north of Spica while Mars lies 4° to Venus' lower right. By then, Mercury has faded to magnitude 0.3 and stands 4.5° directly below Venus. Mercury sets about 40 minutes after the Sun, and both it and Mars soon get lost in the twilight. On the 22nd, Mercury, Mars, and Spica lie within a 4° circle, although bright twilight hinders the view.

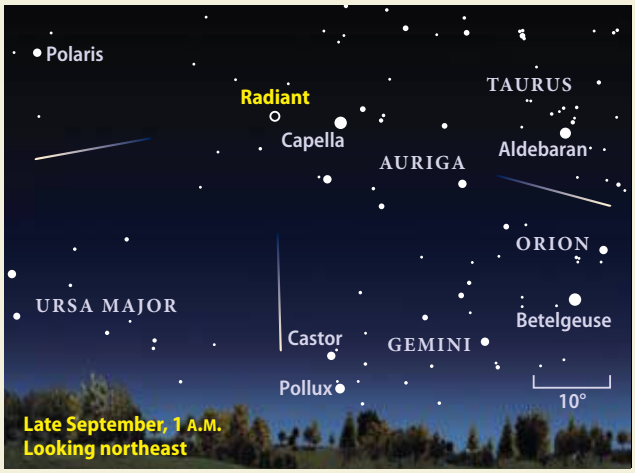
A telescope won't improve Mars' appearance. The Red Planet measures 4" across this month and offers no detail. Mercury fares somewhat better. It begins September appearing 6" across and more than two-thirds lit. By greatest elongation, it's up to 7" in diameter and just over half-lit. The inner planet continues to grow in size and shrink in phase. On the 18th, it appears 8" across and 42-percent illuminated.

Unlike Mercury and Mars, Venus is just beginning a new season of visibility. Venus will continue to hug the southwestern horizon for the next few months, but the beacon will climb higher in the evening sky by year's end.

Not all of the evening planets lie low in the west. As twilight starts to fade, your eyes will be drawn to gleaming **Jupiter** in the southern sky. Shining at magnitude –2.4, it's the second brightest

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc.* **Alister Ling** *is a meteorologist for Environment Canada.*

Meteor watch



A couple of extra meteors will grace the early morning skies each hour during late September as the minor Delta Aurigid shower reaches its peak. *Astronomy*: Theo Cobb

Catch an autumn trail or two

Following an active August, meteor rates fall off significantly in September. A couple of minor showers with low rates add to the count of sporadic meteors, whose rate this time of year reaches close to 10 per hour.

The Delta Aurigid shower peaks in late September, so viewing should be good under the New Moon as September closes. Although observers typically see only a couple of this shower's meteors per hour, they move quickly. To distinguish a Delta Aurigid from a sporadic, plot the meteor's path on a star chart as soon as you see it. Then, trace the track backward to see if it intersects the shower's radiant.

Rising Moon

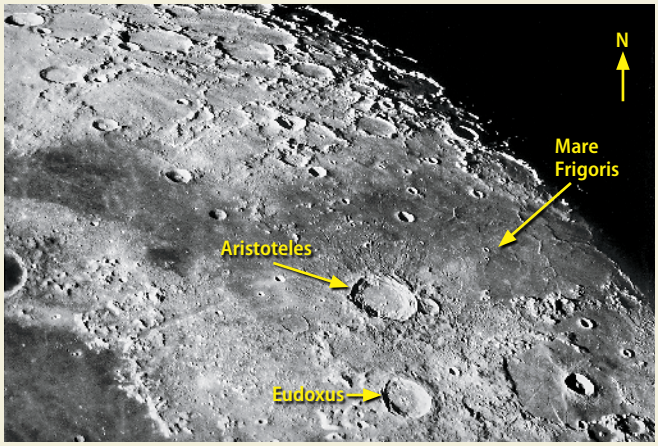
A philosopher scars the Moon

From sunrise through solar noon to sunset, lunar features change their appearance drastically. Some disappear under a high Sun, while others brighten into prominence — only to get lost by late afternoon. Aristoteles looks pretty good most of the time. It ranks among the youngest large lunar craters, and spans a little more than 50 miles. It sticks out of Mare Frigoris, which snakes across the Moon's far-northern latitudes.

Aristoteles' tall rim catches the first rays of sunlight September 5, but its floor remains in complete darkness until the following Earth day. On subsequent evenings, you should notice that Aristoteles does not boast a lone central peak. Instead, it displays a group of jumbled hilltops. In moments of good seeing, a lot of structure pops into view in this region. One example: the large number of small secondary craters created by Aristoteles' impact.

After September 10, use a filter to cut down on glare from the harsh sunlight. The crater's striking detail has vanished, replaced by bright flecks among the remains of the slumped walls. Imagine digging a large hole in wet sand, then watching the edge collapse inward to fill the center.

Just south of Aristoteles and beyond the shore of Mare Frigoris lies the crater Eudoxus. Lighter lunar highlands surround this impact scar, which is slightly smaller than Aristoteles.

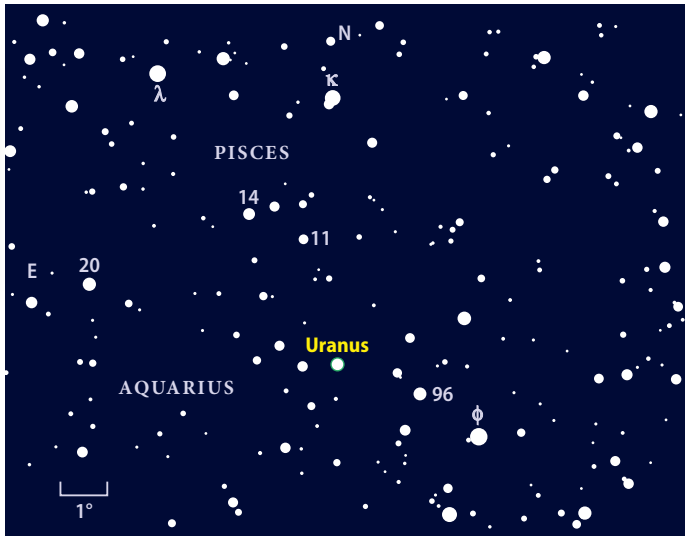


Aristoteles lies on the southern shore of Mare Frigoris. This relatively fresh lunar crater comes into view September 5, about 1.5 days before first quarter phase. *Consolidated Lunar Atlas*/UA/LPL

An observing highlight this month comes September 19, when the Moon captures and releases the Pleiades star cluster. While viewing this event through your telescope, take some time to note the impending sunset on Aristoteles.

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (west)	Uranus (south)	Saturn (east)
Venus (west)		Uranus (west)
Mars (west)		
Jupiter (south)		
Uranus (east)		



Distant Uranus shines biggest and brightest this month — and remains visible all night among the background stars of Aquarius. *Astronomy:* Theo Cobb

planet in the sky after Venus — and no star comes close to it. Jupiter reaches the western end of its retrograde loop September 7/8, when its east-to-west motion against the background stars comes to a halt. Its slow progress this month keeps it above the stars that form the handle of the Teapot asterism in Sagittarius.

When viewed through a telescope, Jupiter shows a noticeably flattened disk wider across the equator (42") than through the poles (39"). The disk bubbles with subtle atmospheric details that pop out with patient viewing. The two most obvious features are the relatively dark north and south equatorial belts.

The current alignment of Jupiter relative to the Sun and Earth means the giant planet's shadow extends into deep space east of Jupiter's disk. As the Galilean moons pass behind Jupiter, they normally would reappear once they clear the eastern limb. This month, the inner moons Io and Europa still lie in the shadow as they come out from behind the planet. They don't become visible until they exit the shadow more than an hour later.

You can watch an example September 22, when Io reappears well east of the planet at 11:27 P.M. EDT. An observer at a specific site can see only a few such events this month between the onset of darkness and the time Jupiter sets.

Neptune reached opposition last month and remains a good binocular target. Glowing at magnitude 7.8, it presents a modest challenge for planet hunters because lots of similarly faint stars populate its region in Capricornus. Fortunately, a trio of stars will help you identify Neptune.

The three stars form a line north-northwest of the 3rd-magnitude star Delta (δ) Capricorni. The brightest one is 42 Cap (at magnitude 5.2), followed by 44 and 45 Cap (both at 6th magnitude). All show up clearly in binoculars. A pair of 7th-magnitude stars lies just west of 45 Cap.

In September, Neptune's path begins 0.9° due west of 44 Cap. The planet heads slowly west-southwest for the remainder of the month. On September 14, it passes 0.4° north of the western star in the 7th-magnitude pair.

Neptune's inner neighbor, **Uranus**, reaches opposition September 12. It then lies opposite the Sun in our sky and stays visible all night. It

Comet search

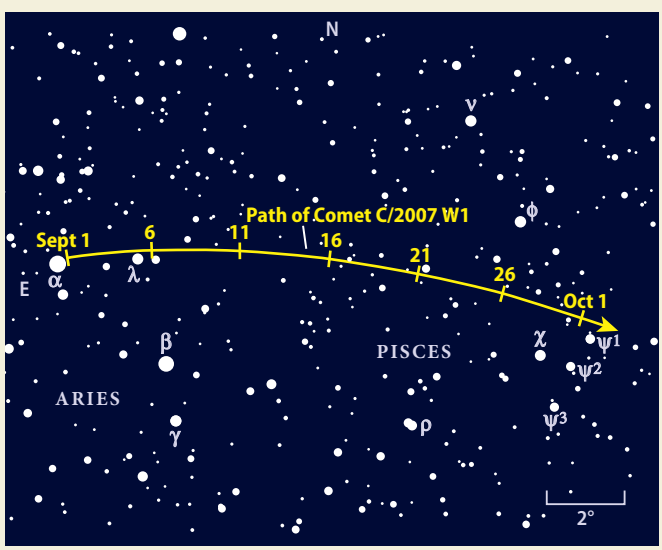
Fishing for a faint fuzzy

Star-party attendees in late August and early September should set their sights on the 10th-magnitude interloper C/2007 W1 (Boattini). It will be well-placed in the east by late evening and remain up the rest of the night. To catch this comet, you'll need to be out under a dark sky and avoid the Moon's unwanted light. As Boattini slides across the back of Pisces the Fish, the comet will resemble some of the fainter Messier objects. You should get a nice view through a 4-inch scope under good conditions.

At best, Boattini will show a stubby tail. The solar system conspires against us this month, because the comet's tail extends mostly behind it from our perspective. In this respect, it mimics last year's appearance of Comet 17P/Holmes.

At September's close, Comet C/2007 W1 passes close to Psi[1] (ψ[1]) Piscium, an easy double star for small telescopes. Its components shine at magnitudes 5.4 and 5.6 and have a comfortable separation of 30". Can you see any color difference between the two stars?

If you're in a comet-hunting mood, lots of other targets await those with bigger scopes. Almost a dozen glow at 12th magnitude or brighter. For up-to-date finder charts and magnitudes, check out aerith.net/comet/future-n.html or www.cometchasing.skyhound.com.



Comet C/2007 W1 (Boattini) glows around 10th magnitude in late August and early September, as it glides from western Aries into northern Pisces. *Astronomy:* Theo Cobb

Kleopatra: beyond the ordinary

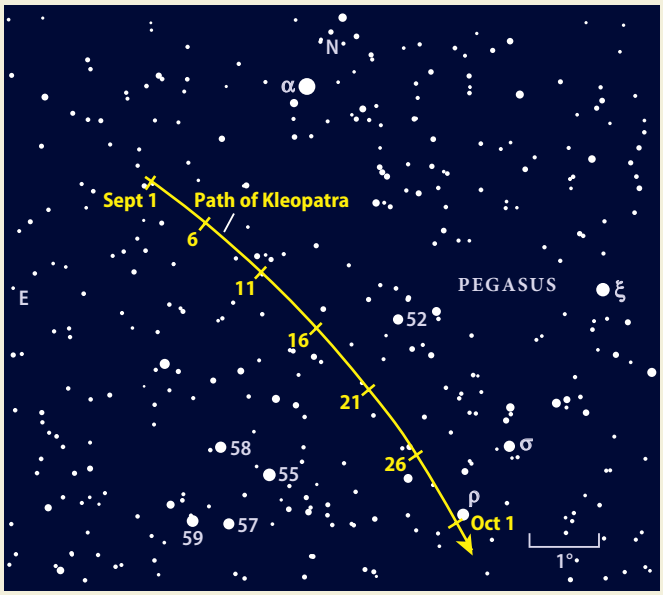
Unusual is a good word to describe the main-belt asteroid 216 Kleopatra. First, it has a high number despite being reasonably bright. Eighteenth-century observers typically discovered asteroids in order of decreasing brightness, so those with bigger numbers tend to be fainter. However, Kleopatra's eccentric orbit brings it in to nearly the inner edge of the main asteroid belt, so it occasionally brightens to 10th magnitude.

Second, instead of being potato-shaped like most modestly large asteroids astronomers have observed closely, Kleopatra looks more like a sausage. On January 19, 1991, Kleopatra passed in front of a star and cast its shadow across the United States. By timing when the star disappeared and reappeared, amateur astronomers collectively helped to determine the object's strange shape.

Finally, most bigger asteroids orbit the Sun close to the ecliptic plane defined by the planets' orbits. But Kleopatra's path inclines 13° to the ecliptic, similar to Pluto's hefty 17°.

Kleopatra spends September near Alpha (α) Pegasi, the star at the lower right corner of Pegasus' Great Square. The asteroid lies just a few degrees south of the star. Because this region borders the Milky Way, many background stars near Kleopatra's brightness occupy the field. On September 11, 17, and 25, the asteroid closes in on 7th- and 8th-magnitude stars, making it easier to identify the space rock and follow its hourly motion. The rest of the month, you'll need to sketch or photograph the field and return a night or two later to see which "star" moved.

The best asteroid occultation of 2008 occurs the night of September 11/12 around 2:30 A.M. EDT, when the large asteroid 9 Metis passes in front of a 6th-magnitude star. Anyone along the main shadow path from Los Angeles to Green Bay, Wisconsin, can view this occultation. But even if you're off this path, it's worth watching. You just might get lucky and see a secondary drop in brightness, signaling the discovery of a moonlet orbiting Metis. For details on this event, visit iota.jhuapl.edu/mp.htm.



Asteroid Kleopatra peaks at 10th magnitude this month as it moves slowly to the south and west just south of the 2nd-magnitude star Alpha (α) Pegasi. *Astronomy:* Theo Cobb

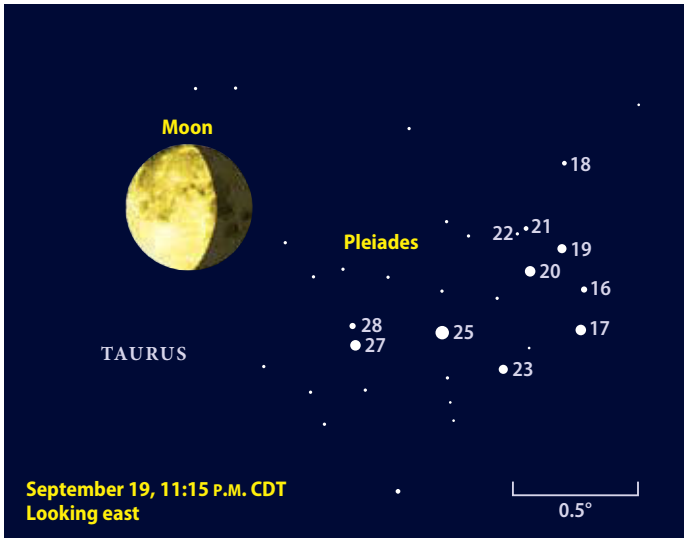
also shines brightest at opposition, reaching magnitude 5.7. For a distant planet like Uranus, its brightness changes little over the course of a month or two, so it remains a good target throughout September. You can spot it easily through binoculars, and glimpse it with your naked eyes from a dark site.

Uranus lies in eastern Aquarius, northeast of 4th-magnitude Phi (ϕ) Aquarii. The planet begins September 4° from this star and ends the month 3° away. The September 14/15 Full Moon passes just 4° north of Uranus. A telescope reveals the planet's 3.7"-diameter disk, which glows with a distinctive blue-green color.

Saturn reaches solar conjunction September 3, when it lies on the opposite side of the Sun from Earth. It then passes into the morning sky, where it becomes visible low in the east by month's end.

You'll want to target Saturn with your telescope for one last look at its dwindling rings. Twice during each of its 29.5-year orbits, Saturn's ring plane turns edge-on to our line of sight. Although this will not happen until 2009, the tilt narrows so much by late this year that seeing the rings will be difficult. The geometry does have an upside. Viewing opportunities will include seeing the planet's moons and their shadows transit Saturn's disk.

As the Moon traverses the sky each month, it frequently passes in front of stars. The most spectacular of these events occurs when the Moon crosses the Pleiades star cluster (M45). As the waning gibbous Moon rises September 19, it will hide many of this cluster's stars. Observers on the East Coast of the United States will see some Pleiads reappear from behind the Moon's dark limb. For those farther west, all of the stars will be in view.

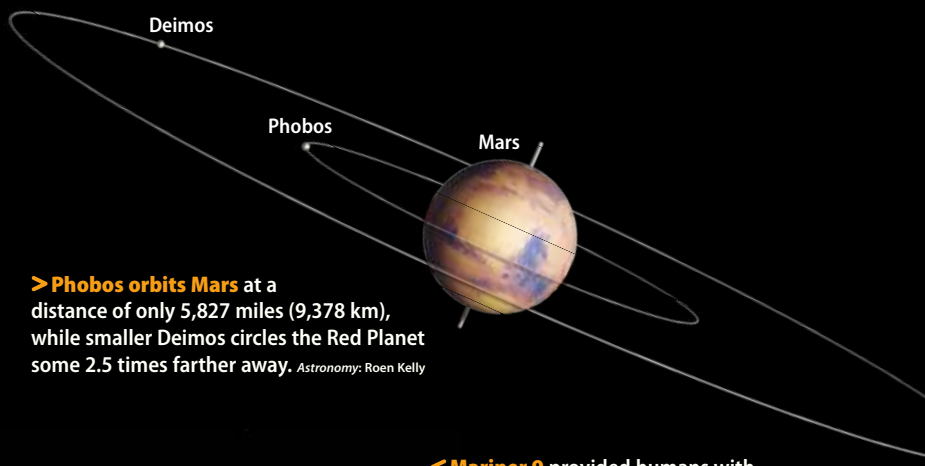


The Seven Sisters — the gleaming star cluster also known as the Pleiades and M45 — receives a visit from a nearly three-quarters-lit waning gibbous Moon September 19. *Astronomy:* Theo Cobb

Meteors rock Phobos

The Red Planet's largest moon bears scars from eons of major impacts.

by Richard Talcott



> Phobos orbits Mars at a distance of only 5,827 miles (9,378 km), while smaller Deimos circles the Red Planet some 2.5 times farther away. *Astronomy*: Roen Kelly

Early in the 17th century, Johannes Kepler (1571–1630) predicted Mars had two moons. The great scientist argued not from a scientific perspective, but from a numerological one. He reasoned that since Venus had no moons, Earth one, and Jupiter four (to his knowledge), Mars naturally would have two.

In August 1877, U.S. Naval Observatory astronomer Asaph Hall (1829–1907) proved Kepler right. Observing Mars during an especially close approach to Earth, Hall discovered two points of light circling the Red Planet. He named them Phobos and Deimos after the sons of Mars in Homer's *Iliad*.

Of the two, Phobos is bigger and more interesting. The oblong moon measures 16.7 by 13.9 by 11.4 miles (26.8 by 22.4 by 18.4 kilometers). It orbits Mars once every 7 hours and 39 minutes at an average distance of just 5,827 miles (9,378 km). And its orbit is slowly decaying: 100 million years from now, it will smash into Mars' surface.

Close-up spacecraft images — including new ones taken by the Mars Reconnaissance Orbiter featured here — show impact craters cover the surface. Biggest of all is Stickney, which measures 5.6 miles (9 km) across. Also prominent is a series of grooves and crater chains that spread across the entire moon. Some scientists think they formed as a result of the Stickney impact, while others believe they could be scars created when ejecta from impacts on Mars later collided with Phobos.

< Mariner 9 provided humans with their first good look at Phobos. The spacecraft was 3,580 miles (5,760 km) from the moon when it snapped this image. NASA/JPL

> The Viking 1 orbiter came within 400 miles (640 km) of Phobos in October 1978. This image mosaic shows the giant crater Stickney, largely in shadow, at upper left. NASA/JPL

^ Mars Global Surveyor shot this image of Phobos in August 1998. With a resolution of 13 feet (4m) per pixel, individual boulders appear on the rim of Stickney (upper left). NASA/JPL/MSSS

^ Mars Express flew within 125 miles (200 km) of Phobos in August 2004. This view of the Mars-facing hemisphere has a resolution of about 23 feet (7m) per pixel. ESA/DLR/FU Berlin (G. Neukum)

Richard Talcott *is a senior editor of* Astronomy.

The Red Planet has two dark companions: the small moons Phobos and Deimos. ESA/Rosetta

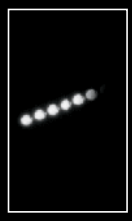
Astronomy magazine

Mars Reconnaissance Orbiter (MRO) took this image March 23, 2008. Stickney dominates the upper left of Phobos, while grooves and crater chains radiate across the rest of the surface. Taken from 4,225 miles (6,800 km), this photo reveals surface detail at 22.3 feet (6.8m) per pixel. NASA/JPL/University of Arizona

Stickney Crater fills the left side of this false-color MRO photo. Material near the rim appears bluish, suggesting it is younger. The walls of Stickney show landslides occur even in the small moon's weak gravity. NASA/JPL/University of Arizona

Opportunity rover captured Phobos crossing the Sun in March 2004. Although Phobos is too small to cause a total solar eclipse, it can block a significant fraction of the Sun's disk. NASA/JPL/Cornell

Phobos' shadow races across Mars' surface in this Global Surveyor photo from August 1999. The shadow doesn't appear totally black because some sunlight reaches the surface during partial solar eclipses. NASA/JPL/MSSS



An eclipse of Phobos occurs when the moon passes into Mars' shadow. In this pictorial sequence, taken by the Spirit rover in November 2005, Phobos doesn't disappear completely because some sunlight passes through the planet's atmosphere and into the shadow. NASA/JPL /Cornell/Texas A&M/SSI

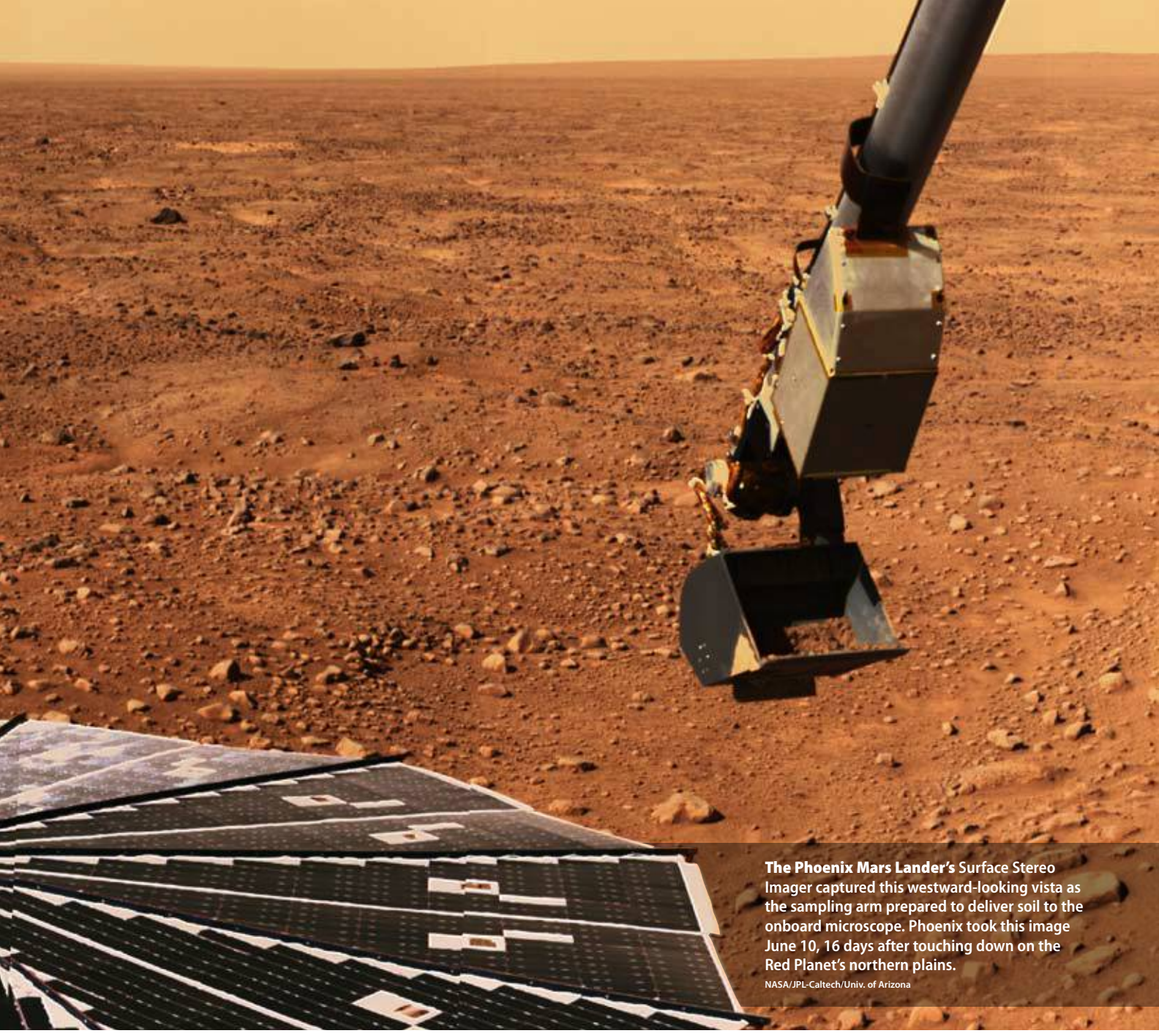
NASA's Phoenix digs Mars

The Red Planet's newest spacecraft delves beneath the surface in search of ice. **by Bruce Moomaw**

Phoenix (illustrated here) set down in Mars' arctic at a latitude equivalent to that of Barrow, Alaska, on Earth. NASA/JPL

On May 25, NASA's Phoenix Mars Lander fired its dozen landing rockets and touched down in the martian arctic. The craft radioed its success to the orbiting Mars Odyssey spacecraft, which relayed the message to Earth. Fifteen minutes later, when the signals reached the Jet Propulsion Laboratory (JPL) in Pasadena, California, cheers and applause erupted throughout the mission's control room.

Bruce Moomaw *is a freelance writer in Cameron Park, California. He has been intensely interested in space exploration since 1965.*



The Phoenix Mars Lander's Surface Stereo Imager captured this westward-looking vista as the sampling arm prepared to deliver soil to the onboard microscope. Phoenix took this image June 10, 16 days after touching down on the Red Planet's northern plains.
NASA/JPL-Caltech/Univ. of Arizona

NASA Administrator Michael Griffin was among those awaiting the signals. "For the first time in 32 years, and only the third time in history, a JPL team has carried out a soft landing on Mars," said Griffin, calling it an "incredible achievement." Apart from the twin Viking landers, which set down in 1976, successful U.S. spacecraft have performed airbag-cushioned "hard" landings.

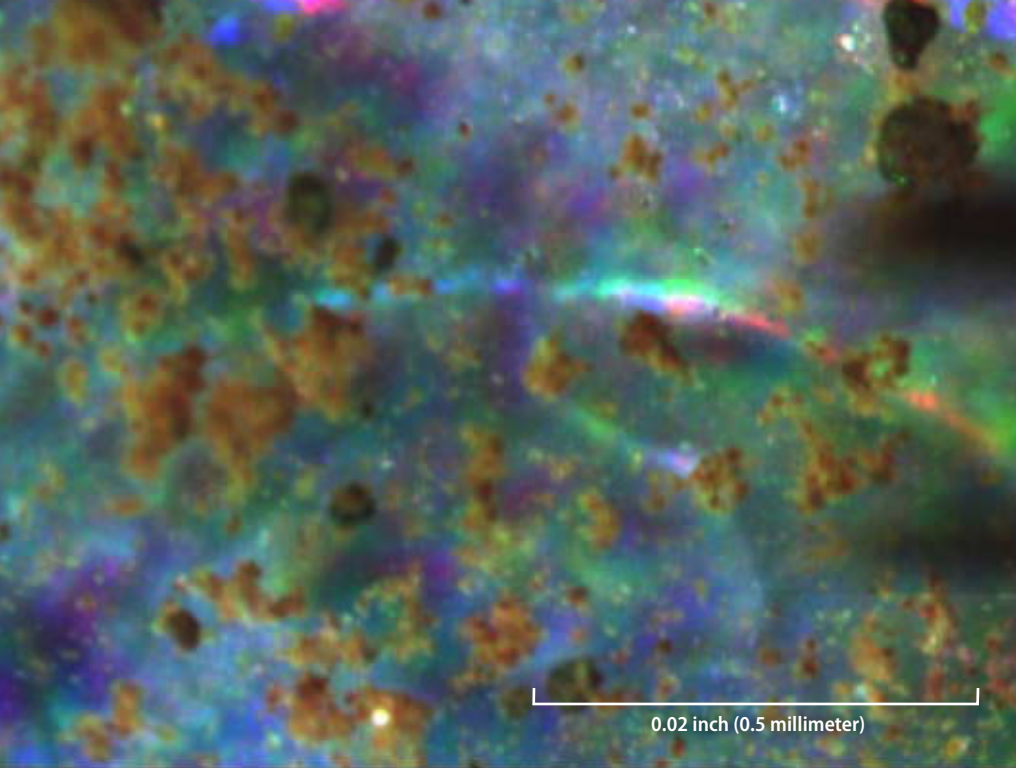
In short order, the $420 million spacecraft unfurled its circular solar panels, began generating power, and got to work. Although Phoenix doesn't carry experiments to detect life, Principal Investigator Peter Smith at the University of Arizona considers it predominantly a biological mission. The most important goal: Dig into an ice layer beneath the landing site and determine if it is, or ever was, capable of supporting life.

Boulders and polygons

Phoenix uses hardware built for the canceled 2001 Mars Surveyor, along with improved versions of instruments that flew on Mars Polar Lander, which was lost during its descent December 3, 1999. Yet, even with an existing spacecraft, the road to Mars was a bumpy one. A critical set of problems revolving around the probe's landing radar required expensive changes that weren't completed until just a few months before the August 4, 2007, launch.

Another unwelcome surprise came in November 2006, when NASA's Mars Reconnaissance Orbiter (MRO) checked out the mission's proposed landing sites. The Phoenix team had spent years analyzing data from other Mars orbiters to locate a smooth, low-altitude, wind-free spot. But MRO's keen vision found the landing area peppered with yard-wide boulders.

This began a frantic last-minute search of three other regions in Mars' northern plains. Luckily, MRO found a boulder-free zone at the same martian latitude.



This microscopic view of martian soil is the highest-resolution view ever of the Red Planet. It's also the first sample collected and analyzed aboard a U.S. planetary lander since the Viking missions of the 1970s. The microscope took this image June 11 (sol 17). NASA/JPL-Caltech/Univ. of Arizona

Gentle hummocks bordered by soil-filled cracks occur throughout the Phoenix landing site. Seasonal expansion and contraction of subsurface ice creates this polygonal terrain on Earth.
NASA/JPL-Caltech/Univ. of Arizona

Phoenix's first views of the landing site showed it to be utterly smooth — a flat plain sprinkled with rocks no bigger than pebbles. Only a malfunction could have caused a crash.

The site's most interesting trait is that the ground is broken up into polygons. These are gentle hummocks a yard or more across, bordered by straight troughs a few inches wide.

As water freezes, it expands, but as the temperature continues to fall, it contracts and splits into separate blocks. The cracks between the blocks fill with dirt in the depth of winter. When spring arrives, the blocks try to expand again, but with dirt filling the spaces between them, they instead buckle upward in the middle. Polygons often occur on Earth's polar landscapes, and their presence at the Phoenix site suggests a near-surface permafrost layer.

Onboard labs

During the first few martian days (sols), Smith and his team carefully inspected pictures from Phoenix's Surface Stereo Imager (SSI). The potential digging area contains a trough between two polygons. The team set aside the rightmost portion of the 12-square-foot (1.1 square meters) area as a "national park" reserved only for science operations. The left portion would be used for the arm's initial tests and for dumping leftover soil after the science instruments have received their samples.

Phoenix hosts two instruments for examining the soil. The first is MECA, short for Microscopy, Electrochemistry, and Conductivity Analyzer. It includes a pronged sensor on the end of Phoenix's sampler arm that measures the electrical and thermal conductivity of soil and ice. Retrieved samples can be poured into six tiny pockets, which swing inside the craft for inspection by a high-powered color microscope. The smallest particles it can see are just 0.00008 inch (2 micrometers) across. Another device, called an atomic force microscope, can examine details smaller than 2 millionths of an inch (0.05 micrometer) on individual grains.

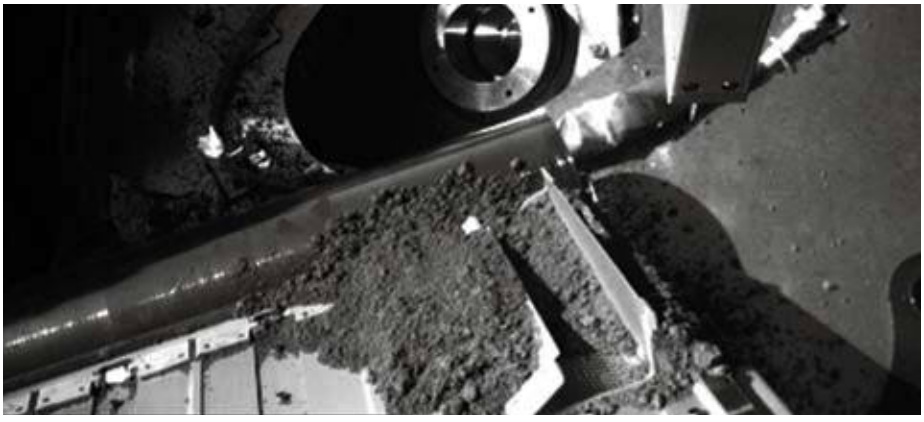
MECA's "wet-chemistry" tests involve samples deposited into cups containing 1 fluid ounce (30 milliliters) of water. Twenty-six different electrodes identify what turns up in the resulting brew. Scientists expect that salts and other substances in the ice layer will precipitate out of any soil that happened to have been moistened during brief melting episodes.

The other laboratory Phoenix carries is the Thermal and Evolved-Gas Analyzer (TEGA). In each of its eight single-use ovens, TEGA heats samples to temperatures as high as 1800° Fahrenheit (1000° Celsius). This converts water and any other volatile ingredients into a stream of gases that can be analyzed and identified by an electronic "nose" called a mass spectrometer.

TEGA will determine whether samples contain any organic compounds, which would be an important result for interpreting the site's habitability. The Viking soil studies failed to find any organics, but they should exist on Mars just from impacting carbonaceous meteorites.

One organic molecule TEGA will look for is methane, which the European Space Agency's Mars Express orbiter detected in the atmosphere. Because methane is quickly destroyed there, the presence of even trace amounts of the gas indicates it's being produced somewhere on Mars.

The Robotic Arm Camera found that the lander's engine exhaust had blown away surface dust to reveal a hard, smooth, light-colored feature (middle) the science team has dubbed "Holy Cow." It could be martian permafrost. NASA/JPL-Caltech/Univ. of Arizona/Max Planck Institute



Getting samples into the Thermal and Evolved-Gas Analyzer's (TEGA) tiny oven required a shake before the bake. Using the oven doors, controllers shook the clumpy soil seven times before enough of it passed through the oven's screen to test. NASA/JPL-Caltech/Univ. of Arizona/Max Planck Institute

A mysterious white layer occurs in the "Dodo-Goldilocks" test trench the probe's robot arm dug. Within 4 martian days, dime-sized fragments from this layer evaporated. The temperature is too warm for dry ice (CO_2) to exist, so scientists concluded the fragments were frozen water. NASA/JPL-Caltech/Univ. of Arizona/Texas A&M Univ./SSV

Rounding out Phoenix's main science instruments is a Canadian meteorology package that provides the first look at Mars' polar weather. Activated within an hour after the landing, the station reported temperatures ranging from –112° F (–80° C) in early morning to –22° F (–30° C) in the afternoon.

In addition to measuring temperature, pressure, humidity, and wind speeds, the station uses a laser to determine cloud thicknesses and altitudes directly above the site. This "lidar" also distinguishes dust clouds from those containing frozen water.

Dig it

Even before Phoenix grabbed its first scoop of martian soil, the camera on its robot arm saw an astonishing hint that ice lies near the surface. Scientists angled the arm so the camera could peer under the spacecraft's landing engines, where the exhaust blew away surface dust. The camera imaged a hard, smooth, light-colored patch about a yard long. Smith admitted it was hard not to believe this was a patch of frozen water.

Another hint came a week after landing, when the arm scooped up soil as practice for science sampling. The scoop uncovered a layer of white material in the trench it dug, which suggested the presence of ice or salt. A second test dig revealed more of this curious layer.

By June 8 (sol 14), clumpy soil made it to TEGA's number 4 oven after several days spent shaking the screen to get particles through it. "There's something very unusual about this soil, from a place on Mars we've never been before," Smith says. "We're interested in learning what sort of chemical and mineral activity has caused the particles to clump and stick together."

On June 19 (sol 24), when Phoenix imaged the test trenches it enlarged 4 days earlier, fragments from the white layer had vanished. "It must be [water] ice," Smith says. "These little clumps completely disappearing over the course of a few days, that is perfect evidence that it's ice."

As we go to press, TEGA continues baking its first sample and Phoenix has dug its first trench in the science sampling area. The race is on to characterize the site before its brief summer ends.

Lack of sunlight will cut the probe's power, and controllers don't expect Phoenix will survive the frigid polar winter. But the findings from this first-ever mission to the martian arctic will give planetary scientists much to consider for years to come.

Explore the southern Milky Way's dark clouds

Dusty webs sprawling across the galaxy's richest star fields make for must-see observing.

by Craig Crossen; photos by Gerald Rhemann

Our Milky Way Galaxy is a dirty place. So much soot and dust occupies interstellar space that we see less than 20 percent of the light from the brilliant Perseus Double Cluster (NGC 869 and NGC 884). But for all dust takes away, it also helps create some of the finest cosmic vistas. In fact, we usually take note of them only when they lie between us and a star-rich patch of the galaxy.

Microscopic grains of carbon (ordinary soot), ice (water), silicates (sand), and even some metals (notably iron from certain types of supernovae) compose interstellar dust. The dust gathers in clumps and clouds. The thickest clouds shield their interiors from starlight, which makes them cool enough that space's ever-present hydrogen gas can exist in its molecular form. That's why astronomers call the densest of these regions molecular clouds.

The northern Milky Way's most famous dust feature is the Great Rift that runs through Cygnus, Vulpecula, Aquila, and Serpens. This is actually a chain of dust clouds. Its northeast end, near Deneb, lies about 2,300 light-years away, but the clouds in southern Serpens approach much closer to us.

Glories of the Southern Crown

Less sprawling, but just as photogenic, is a chain of small molecular clouds (SMCs) that stretches along the Milky Way between Scorpius and Crux. The clouds lie a few hundred light-years away and now produce clusters of modest-mass stars. The Rho (ρ) Ophiuchi cloud complex is one of the most frequently imaged. The star lies 3° north of Antares and is some 700 light-years away from Earth.

Nearby, but less well known, is a compact, 1°-long cloud named **Bernes 157**. It's the heart of the Corona Australis Dark Cloud Complex about 420 light-years away, which makes the clumpy, ragged Bernes SMC about 8 light-years long. At its thickest, the cloud's dust squelches light from newborn stars by 35 magnitudes. These baby stars can be mapped only in the infrared by sensing dust their light has warmed.

The blue nebulosities around these stars are reflection nebulae, where dust preferentially scatters blue light. One of these, NGC 6729, includes some pink flourishes. They mark where emission from ionized hydrogen gas supplements the reflected starlight.

Why so little pink in photographs of Bernes 157? The cloud produces stars of spectral type B1 or cooler. Stars this cool don't emit much ultraviolet light energetic enough for ionizing hydrogen atoms. Hotter O-type stars, which ionize hydrogen for scores of light-years around them, create the diffuse glow of all of the sky's great emission nebulae.

Globules in the Chamaeleon

Our next stop is a group of SMCs about 520 light-years away toward the small southern constellation of Chamaeleon. The **Chamaeleon Cloud Complex,** located on the extreme southern edge of the Milky Way near Crux, is similar to the Corona Australis Complex, but much clumpier.

The Chamaeleon Cloud Complex contains dust that reflects the blue light of nearby B-type stars. Nebula IC 2631 (left) is the brightest example. The clouds lie 520 light-years away.

Craig Crossen *and* **Gerald Rhemann** *co-wrote* Sky Vistas: Astronomy for Binoculars and Richest-Field Telescopes *(Springer-Verlag, 2004).*

NGC 5367 in Centaurus is a reflection nebula on a comet-shaped cloud called CG 12.

The hottest stars produced in the Chamaeleon Cloud are type B1, so we see mostly blue reflection nebulae. In photographs, a few pink areas glow where energetic starlight manages to make hydrogen gas fluoresce.

Several cloudlets look particularly dark. These are Bok globules, spherical clouds between about 0.3 and 7 light-years across. The smallest ones will dissipate before they can condense into stars. Medium-size globules can produce a single Sun-like star, and larger globules may form multiple-star systems. Astronomers estimate 100,000 of these mini-clouds populate our galaxy.

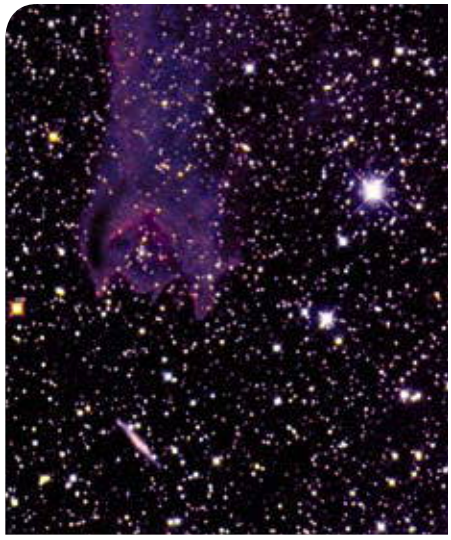
Fringed in dust and gas

The clumps of dust thin quickly as we look even slightly out of the Milky Way's plane. For an example, consider a patch of faint emission nebulosity in the southern constellation of Apus.

This is not a star-forming region, just a gauze of gas and dust. The material is so thin that three external galaxies shine through it. IC 4633 is conspicuous on the edge of the emission glow. In the midst of the nebular haze lies the bright sliver of a distant edge-on spiral or lenticular system. Across the nebula from IC 4633 resides a third galaxy — just a smudge, because it's farther away than the others.

Open cluster NGC 6193 contains two fiercely hot O-type stars that erode and illuminate the surrounding nebula, NGC 6188. Their energy brightens the rim of the molecular cloud that formed the cluster and is sweeping it away. The cluster lies 4,300 light-years away.

An unnamed Bok globule's matter (top) flows away from O stars in the nearby open cluster NGC 6231 (bottom right) in Scorpius. Intense radiation and strong outflows from these exceedingly hot stars can clear out a molecular cloud in less than half a million years. NGC 6231 is 6,200 light-years away.



Comet-shaped cloud CG4 in Puppis is illuminated and sculpted by stars in open cluster Melotte 66. Thanks to pincer-like projections at the cloud's large end, CG4 seems to be trying to grasp a faint background galaxy. The cloud is 1,300 light-years away.

This patch of faint emission in the southern constellations of Apus and Octans is not part of a star-forming region. It's just a thin haze of gas and dust above the galaxy's plane. The cloud is so thin, three galaxies — including IC 4633, the brightest — shine through it.

Another example occurs northeast of the rich, but distant, open cluster Melotte 66 in Puppis. However, a feature known as **Cometary Globule 4** (CG4) shows this area of interstellar matter is considerably dustier than that in Apus.

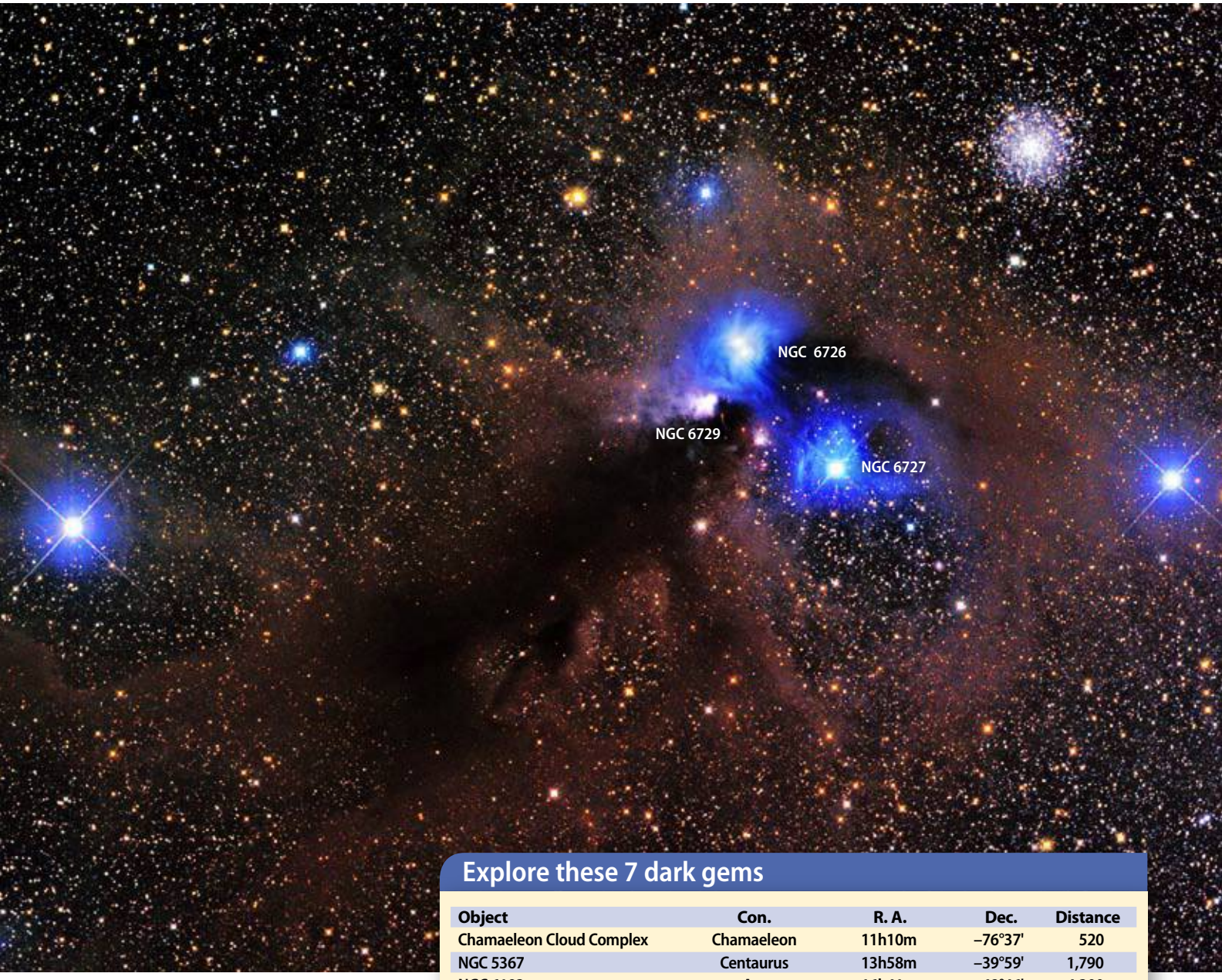
Cometary globules are isolated, relatively small clouds of gas and dust within the Milky Way. CG4 lies about 1,300 light-years away and contains enough material to make several Sun-sized stars. CG4 sports two extensions that resemble the pincers of a claw. Seemingly within their reach is a faint edge-on galaxy.

The fact that a galaxy is visible at all tells how thin and localized the dust here is. Indeed, Puppis is the Milky Way's least dusty region. Along certain lines of sight, dust dims stars 20,000 light-years away by just 3 magnitudes.

Somehow, gas and dust rise hundreds of light-years out of the galaxy's plane. Astronomers find their subtle infrared and ultraviolet glow even near the galactic poles. In those wavelengths, these high-latitude clouds reflect the galaxy's cumulative light.

Hot stuff in Ara

A nest of hot, young O stars can clear out a molecular cloud in less than half a million years. One beautiful example is open cluster **NGC 6193** and its associated nebula NGC 6188 in Ara. What remains of the original molecular cloud forms a dark shoreline-like edge on one side of the



Bernes 157 is the heart of the Corona Australis Dark Cloud Complex about 420 light-years away. Three reflection nebulae — NGCs 6726, 6727, and 6729 — flare in the cloud's northern end (right). NGC 6729 has a touch of pink, which indicates its star is setting some gas aglow.

Explore these 7 dark gems

Object	Con.	R. A.	Dec.	Distance
Chamaeleon Cloud Complex	Chamaeleon	11h10m	–76°37'	520
NGC 5367	Centaurus	13h58m	–39°59'	1,790
NGC 6193	Ara	16h41m	–48°46'	4,300
NGC 6231	Scorpius	16h54m	–41°49'	6,200
Melotte 66/CG4	Puppis	7h27m	–47°44'	1,300
Faint emission around IC 4633	Octans	17h14m	–77°32'	—
Bernes 157	Corona Australis	19h02m	–36°53'	420

Con. = Constellation; R.A. = Right ascension (2000.0); Dec. = Declination (2000.0); Distance = light-years

cluster. Stellar winds and radiation crash into the cloud's edge, creating a thin, bright excitation zone — a rim nebula.

Scorpius O stars

In the southwest corner of Scorpius' tail lies **NGC 6231,** one of the most impressive clusters of O-type giants and supergiants known in the galaxy. NGC 6231 is only a couple of million years old, but it has already cleared gas and dust for scores of light-years around it. A comet-shaped dust cloud, a remnant of the massive one that birthed NGC 6231, shows how O-star winds and radiation erode Bok globules. The cluster is blowing gas and dust away from the cloud. Even in such a hostile environment, a globule far enough from the cluster can produce a new star before it completely disintegrates.

Calm winds in the Centaur

Not all comet-shaped clouds are true cometary globules. The cloud that hosts reflection nebula **NGC 5367** in Centaurus is a good example. There are no O-type stars here, just the light of a B-type sun scattered by dust. With no rim nebula, we can conclude this cloud owes its shape to something other than the winds and radiation of hot stars.

Don't overlook some of the galaxy's darker views. The interplay of bright stars and dark molecular clouds is a pleasing sight — and it adds a seemingly 3-D perspective to your Milky Way tours.

Ask Astro

Astronomy's experts from around the globe answer your cosmic questions.

How did ancient stars get uranium?

Q: With lots of elements like uranium, how can the star HE 1523–0901 be 13.2 billion years old? — **Patrick E. Wondra,** Pennington, Minnesota

A: Prior to HE 1523–0901's birth, supernovae produced heavy elements like uranium, europium, and thorium by a process called neutron capture. So, **HE 1523–0901 formed from gas that already was enriched in these heavy elements.**

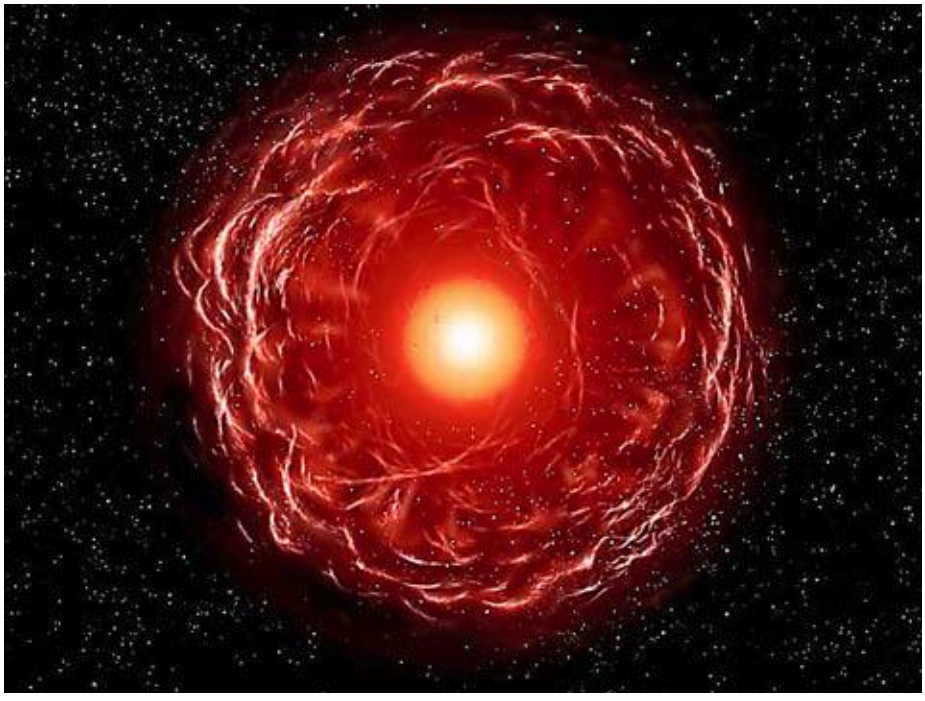
But the first supernovae didn't produce much in the way of lighter elements, like iron. So, the iron in HE 1523–0901 reflects the proportion of lighter elements already in the gas that formed the star.

Because there's so little iron, astronomers know the star must be extremely old. HE 1523–0901's enrichment in radioactive elements allows us to work out its age.

The star's thorium and uranium came from a first- or second-generation supernova. Otherwise, when HE 1523–0901 formed, interstellar gas would have contained more iron. It's hardly possible to lower the chemical abundances of interstellar gas, but it's easy to increase them with the contributions of different types of supernovae.

Astronomers now are debating the exact timescales of the first stars' evolution, but things happened quickly. The first stars exploded as supernovae after only a few million years. HE 1523-0901 probably formed soon thereafter.

— **Anna Frebel,** University of Texas at Austin



HE 1523–0901, illustrated here, is one of the oldest stars known. The 0.8-solar-mass red giant lies 7,500 light-years away in Libra. The star's lack of iron already indicates it formed when the universe was young. Thanks to a rare combination of "cosmic clock" elements, astronomers established the star's 13.2-billion-year age. ESO

ASTEROIDS vs. COMETS

Q: What is the difference between comets and asteroids?

— **Carole Meshaw,** Watha, North Carolina

A: Asteroids and comets are rocky or icy solar-system objects ranging in size from less than half a mile to many hundreds of miles wide. Traditionally, astronomers have assumed that asteroids formed in the inner solar system without much ice content, while comets formed in the outer solar system where ice was more plentiful. When a comet passes close to the Sun, ice on its surface sublimates (turns to a gas) to produce a beautiful coma and tail. Asteroids should not be able to do this.

But new observations increasingly blur the lines between the two classes. For example, a few asteroids sport sporadic tails that make them look like comets. Alternatively, comets, in the process of shedding material, leave a lot of gunk behind on their surfaces that, in some cases, makes them look like asteroids. For this reason, astronomers commonly use confusing words like comet-like asteroids and asteroid-like comets. — **Bill Bottke,** Southwest Research Institute, Boulder, Colorado

WEIGHING BLACK HOLES

Q: How do astrophysicists measure a black hole's mass?

— **Kirt Bhatt,** Columbia, Maryland

A: If the black hole is sitting by itself out in space, you probably won't be able to see it at all, since all light falling on it will be absorbed. After all, that's why it's called "black." The way you learn anything about a black hole is by seeing how it interacts with ordinary matter and radiation around it.

Suppose you have a double-star system, with one of the stars being massive. In a short time, astronomically speaking, that star will run through all of its fuel, explode as a supernova, and leave behind a remnant black hole. Now you have an

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GLOSSARY OF TERMS

Abundance
The quantity of a chemical element in a star relative to the amount found in the Sun.

Elliptical galaxy
A galaxy with little gas, random star motions, and an elliptical shape.

Neutron capture
A set of processes that enables stars to build up elements heavier than iron when the flux of neutrons is high, as in a supernova.

Spiral galaxy
A galaxy composed of a flattened, star-forming disk and a large central bulge from which spiral arms appear to unwind.

Supernova
The near-total destruction of a star; a small, remnant black hole or neutron star often is left behind.

ordinary star and a black hole in orbit around each other.

Astronomers can measure the pair's rotation period by looking at the star's emitted light. When the star's orbit carries it toward you, its light will be slightly blueshifted. When the star is moving away, the light will be redshifted. The time it takes to cycle through these changes establishes the pair's orbital period.

The visible star's temperature and spectrum let astronomers estimate its mass. Once they have that, simple dynamics lets them estimate the unseen partner's mass.

Astronomers use a similar technique to determine the masses of huge black holes in the center of galaxies. There, they study the mass of hot gas swirling around and falling into the galaxy's center instead of a companion star.

It's theoretically possible to estimate the mass of an isolated black hole by seeing how it acts as a gravitational lens, bending light that comes near it and distorting the images of distant objects. This technique has not yet been put into practice for black holes, although it's often used to estimate the galaxy masses.

— James Trefil, George Mason University, Fairfax, Virginia

The dark nebula Barnard 68 is a Bok globule on the verge of collapse and, eventually, star formation. The cloud contains more than twice the Sun's mass, its gas has a temperature of –431° Fahrenheit (–257° Celsius), and it lies 410 light-years away. J. Alves/R. Fosbury/R. Hook/VLT FORS2 Team

Q: What is a Bok globule?

— Sam Platts, Sylmar, California

A: A Bok globule is a compact dark nebula first recognized by Dutch-American astronomer Bart Bok (1906–1983). Dust makes up about 1 percent of these clouds by mass. Cold gas constitutes the rest.

Many bright nebulae contain Bok globules. They can take different shapes because radiation from nearby hot, young stars erodes and sculpts them. Many globules appear to be collapsing, which paves their way to make new stars.

— Michael E. Bakich, Senior Editor

Q: Do all spiral galaxies eventually become elliptical galaxies?

— Karl Schroeder, Sacramento, California

A: No. Spiral galaxies that enjoy an isolated existence — and those that simply suffer the accretion of many dwarfs — will retain their identities as spirals.

A spiral galaxy has a rotating disk of young stars, old stars, and gas, whereas an elliptical is a ball of old stars with little or no gas. Most isolated galaxies are spirals, whereas those in clusters often are ellipticals.

A spiral's disk is a fragile thing. A collision with a dwarf galaxy will temporarily "puff up" the disk, making it thicker for several billion years. A major merger — the collision of two equal-mass galaxies — might destroy the disk altogether.

In a major merger, a final burst of star formation will consume the galaxies' gas and randomize stellar orbits. The end product here seems likely to be an elliptical galaxy — but it's important to remember that mergers aren't necessarily responsible for creating all ellipticals.

— Richard S. Ellis, Caltech, Pasadena, California

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Discover 10 top Milky Way delights

From Sagittarius to Cassiopeia, late summer offers a lot to observe.

by Michael E. Bakich

If you're a person who lingers until April 15 to file your taxes, chances are you still are hoping to observe summer deep-sky objects. Well, you're in luck. Just because June and July are memories doesn't mean the summer Milky Way has disappeared.

This time of year offers observers the chance to catch a last glimpse of sinking summer highlights and a first look at some fall beauties. We'll start the tour in the southwest and work northward.

As you follow this guide, prioritize your observing the same way. View your targets in order so you don't miss any on the list's first half. You'll have several months to catch the rest of them.

Swing low to Sagittarius

I consider our first object — the **Lagoon Nebula** (M8) — one of the sky's top three nebulae. To find it, move 6° north of magnitude 3.0 Gamma (γ) Sagittarii.

At 1.5° wide, M8 would take three Full Moons — side by side — to cover it. Early observers dubbed this object the Lagoon Nebula because of the dark lane winding through it. This sinuous path, composed of dust and cold gas, blocks light from stars and hotter gas behind it.

The brightest star west of this lane, 6th-magnitude 9 Sagittarii, sets the nebula aglow. M8's core lies a bit more to the west. This brilliant region contains the Hourglass Nebula, a star-forming region bristling with lots of newly formed suns.

Astronomers classify the Lagoon Nebula as an emission nebula because the object's glow comes from light its gas emits. The light contains only certain wavelengths, so a nebula filter will help you see it better.

The Lagoon Nebula (M8) in Sagittarius is a maelstrom of bright and dark nebulosity that looks impressive through any size telescope. It measures 3 Moon-widths across. Tony and Daphne Hallas

Globular cluster M22 in Sagittarius is the third-brightest such star cluster. It glows at naked-eye magnitude 5.2. View it early in the evening before it sinks too low in the west. Lee C. Coombs

Nebula filters come in two categories: broadband and narrowband, based on the breadth of wavelengths they pass. Which should you use? If your telescope measures 6 inches in aperture or less, choose a broadband filter. Often, broadband filters have labels like "Deep-sky" or "Light-pollution reduction."

A filter labeled OIII is an example of a narrowband filter. They work best on telescopes with large apertures — and light-collecting power — because the filters allow far less light through.

Be sure to remove your nebula filter before you look at globular cluster **M22**. Because M22 comprises only stars, any filter will dim the object, reducing contrast between it and the sky background.

Although it never attains high altitudes for most northern observers, M22 is a showpiece through telescopes of all sizes. A 4-inch scope at 150x reveals a couple dozen individual stars around a brilliant center. But view M22 through a 10-inch instrument at 200x, and you'll see a swarm of several hundred stars.

M22 glows at easy naked-eye magnitude 5.2. That light output ranks it as the third-brightest globular cluster in the sky. Only the far-southern globulars Omega Centauri (NGC 5139) and 47 Tucanae (NGC 104) outshine it.

Michael E. Bakich *is a senior editor of* Astronomy *who loves the summer sky.*

The Wild Duck Cluster (M11) in Scutum the Shield is a naked-eye object from a dark site. Through a medium-sized telescope, you'll spot 100 of its stars. Lee C. Coombs

Planetary nebula NGC 6781 in Aquila requires a dark site and an OIII filter for best viewing. Radiation from nearby stars is dissipating the nebula's near-perfect ring. Adam Block/NOAO/AURA/NSF

Move north one constellation to find the **Wild Duck Cluster** (M11) in Scutum. In 1844, English observer William Henry Smyth (1788–1865) gave the cluster its common name. He described M11 in *A Cycle of Celestial Objects*: "This object, which somewhat resembles a flight of wild ducks in shape, is a gathering of minute stars with a prominent 8 mag. star in the middle and two following."

M11 appears at its best through an 8-inch telescope with an eyepiece that gives a magnification of 75x. Through this combo, you'll see more than 100 stars. The Wild Duck Cluster's central region will look like a poor globular until you widen your view somewhat. Concentrate on the streamers of stars and dark lanes emanating in all directions.

Prepare for planetaries

Our next three targets are planetary nebulae — spherical shells of gas blown off Sun-like stars that have died. The first, **NGC 6781**, sits in Aquila. This expanding bubble of gas is almost perfectly circular. Currently, it measures some 2 light-years across. But, in 10,000 years, NGC 6781 will have expanded beyond the distance where its central star (now a white dwarf) can excite the shell's gas. At that point, it will stop glowing.

Through a 6-inch scope, note how NGC 6781 stands out against a star-filled background. Its disk appears as a soft, irregular oval with a slightly darker center. An OIII filter will improve your view.

All planetary nebulae emit light from glowing oxygen atoms. Specifically, these atoms have been ionized twice. This means a photon of light from the central star has moved one of the atom's electrons up two energy levels. Chemists designate neutral oxygen as OI, so doubly ionized oxygen is OIII. An OIII filter passes only wavelengths of light associated with doubly ionized oxygen.

The **Dumbbell Nebula** (M27) lies in the small constellation Vulpecula the Fox. To find it, look 3.2° north of the magnitude 3.5 Gamma (γ) star of another small constellation, Sagitta the Arrow. On July 12, 1764, French comet-hunter Charles Messier (1730–1817) discovered the Dumbbell, making it the first planetary nebula ever sighted.

Small telescopes will show two bright lobes, which give M27 its common name, with several stars scattered across the face. M27 responds well to high magnification because of its surface brightness. Through a 10-inch scope, magnifications of 300x and higher show striations crossing the Dumbbell's inner region.

Next, head to the small but bright constellation Lyra the Harp. Nestled midway between 3rd-magnitude Beta (β) and

Top 10 must-see Milky Way treats

Object	Con.	Type	R. A.	Dec.	Mag.	Size
M8	Sagittarius	Emission nebula	18h04m	–24°23'	6.0	90' by 40'
M22	Sagittarius	Globular cluster	18h36m	–23°54'	5.2	32'
M11	Scutum	Open cluster	18h51m	–6°16'	5.3	14'
NGC 6781	Aquila	Planetary nebula	19h18m	6°32'	11.4	1.8'
M27	Vulpecula	Planetary nebula	20h00m	22°43'	7.4	8' by 5.7'
M57	Lyra	Planetary nebula	18h54m	33°02'	8.8	1.4' by 1'
NGC 7000	Cygnus	Emission nebula	20h59m	44°20'	—	120' by 100'
IC 5146	Cygnus	Emission nebula	21h54m	47°16'	7.2	12'
NGC 7662	Andromeda	Planetary nebula	23h26m	42°32'	9	2.2'
NGC 457	Cassiopeia	Open cluster	1h20m	58°17'	6.4	20'

Con. = Constellation; R.A. = Right ascension (2000.0); Dec. = Declination (2000.0); Mag. = Magnitude

The Dumbbell Nebula (M27) was the first planetary nebula discovered. Charles Messier found it July 12, 1764. M27 shines at magnitude 7.4 in the small constellation Vulpecula the Fox. The nebula measures 8' by 5.7' and lies 1,250 light-years away. Joe and Gail Metcalf/Adam Block/NOAO/AURA/NSF

The Ring Nebula (M57) in Lyra is a favorite summer-sky target. You'll find it midway between Beta (β) and Gamma (γ) Lyrae. Mark Hanson

The North America Nebula (NGC 7000) in Cygnus measures 2° across. Its diffuse glow lies approximately 3° southeast of the bright star Deneb (Alpha [α] Cygni). Peter Roth

Gamma Lyrae lies the **Ring Nebula** (M57). Because it sits high in the northern summer sky, the Ring Nebula probably ranks as the sky's most observed planetary nebula.

The ring looks round, but only in a general sense. Through a 6-inch or larger telescope from a dark site, M57 appears oval-shaped and elongated in an east-west direction. Through a 12-inch scope, you'll see that the ring's disk appears fainter at the oval's ends.

Continue to Cygnus

From a dark site, sharp-eyed observers can see the **North America Nebula** (NGC 7000) with their naked eyes. Look roughly 3° east of Deneb (Alpha [α] Cygni). Averted vision — looking slightly away from a faint celestial object — will help you locate its densest regions.

The whole continent will not be apparent at first glance. Start by finding the brightest part — Mexico — then patiently try to see the rest with averted vision. Don't give up trying to find it with your eyes until you've searched through a broadband nebula filter.

Low-power telescope views with at least a 2° field of view are best for NGC 7000. (Don't forget the nebula filter.)

Our next object, the **Cocoon Nebula** (IC 5146) lies east of the North America Nebula in a nondescript region of Cygnus. Look 3.7° east-northeast of 4th-magnitude Rho (ρ) Cygni.

The Blue Snowball (NGC 7662) is a planetary nebula in Andromeda. A magnification of 100x reveals its color. Adam Block/NOAO/AURA/NSF

The Owl Cluster (NGC 457) lies in Cassiopeia. Through a 6-inch scope, unresolved Milky Way stars create a luminous backdrop. Anthony Ayiomamitis

The Cocoon Nebula (IC 5146) shines at magnitude 7.2 but is a challenge to view because of its low surface brightness. It abuts the dark nebula Barnard 168. R. Jay GaBany

The Cocoon Nebula overlaps the eastern edge of Barnard 168, one of the northern sky's finest dark nebulae. From a good site, sharp-eyed observers can pick up this 1.7°-long and 0.2°-wide murky lane without optical aid, but it's not easy. A better approach is to use 50mm or larger binoculars or a telescope/eyepiece combo that yields more than a 1° field of view.

You can spot the Cocoon Nebula through a 4-inch scope as a circular blur. Its light equals that of a 7th-magnitude star, but the nebula's surface brightness is low. To make matters worse, two magnitude 9.7 stars lie entangled within the glow. For the best view, use at least an 8-inch telescope with magnification around 150x and a nebula filter.

A pair of northern wonders

The aptly named **Blue Snowball** (NGC 7662) is a great object to observe if you're looking for (or showing someone) color in a deep-sky object. Through an 8-inch telescope, NGC 7662 appears as a small, evenly illuminated disk. Magnifications between 50x and 100x works best.

To find the Blue Snowball, start at magnitude 4.3 Iota (ι) Andromedae, and head west to 13 Andromedae. Then move 0.4° south-southwest.

Our tour's final object, the **Owl Cluster** (NGC 457), got its common name in 1977. That year, current *Astronomy* Editor David J. Eicher saw an owl figure made of the cluster's two brightest stars and its overall shape, and he gave NGC 457 its common name.

NGC 457 contains two dozen stars brighter than 12th magnitude. Its most luminous shines at magnitude 8.6. A 6-inch telescope at 50x shows nearly 75 cluster stars. Behind the cluster, unresolved Milky Way stars provide a uniform background glow.

Just a taste

This list of late-summer celestial treasures will get you going, but it's just a start. Hundreds of deep-sky objects lie along the Milky Way in full view of small telescopes. That's more than enough to keep you observing through fall.

Check out these great double stars along the way

Designation	R. A.	Dec.	Magnitudes	Separation
Omicron Ophiuchi	17h18m	–24°17'	5.2, 6.8	10"
70 Ophiuchi	18h05m	–2°30'	4.2, 6.2	5"
Beta Sagittarii	18h18m	–36°46'	4.0, 7.4	28"
11 Aquilae	18h59m	13°37'	5.7, 9.2	17"
Eta Lyrae	19h14m	39°09'	3.1, 7.8	3.6"
Beta Cygni	19h31m	27°58'	3.1, 5.1	34.4"
Omicron Cygni	20h14m	46°44'	3.8, 4.8, 6.7	101", 338"
Gamma Delphini	20h47m	16°07'	4.4, 5.0	9"
Eta Cassiopeiae	0h49m	57°49'	3.4, 7.4	13"
Gamma Andromedae	2h04m	42°20'	2.3, 5.5	9.8"

R.A. = Right ascension (2000.0); Dec. = Declination (2000.0)

For definitions of terms, log onto www.Astronomy.com/toc.

Easy imaging with the DSI III

Meade's Deep Sky Imager III offers the options of more expensive CCD cameras.

by Mike D. Reynolds

Many amateur astronomers have looked at the incredible images taken by others and thought, "I wish I could take photographs like that!" With the move from film to charge-coupled device (CCD) cameras, it's easier than ever to take great pictures. Meade Instruments' newest CCD, the Deep Sky Imager (DSI) III, which retails for $1,299, offers an excellent mid-price option.

The DSI III has a larger CCD chip than previous DSI models along with several new or improved features. It is available as either a black-and-white (DSI PRO III) or color (DSI III) camera. If you're just starting out, it might be to your advantage to get the color model. This camera would allow you to take lower-resolution color images.

Producing color photographs with a monochrome CCD camera requires multiple exposures through three filters. Then, you stack these images using software. Stacking allows you to produce higher quality images by putting in a little more effort and time with the monochrome model.

Most beginning astrophotographers think color images are the final goal. This is not necessarily true. Occasionally, monochrome images are not only more pleasing but also provide more data. If you choose to go with a monochrome CCD as your first camera, I recommend that you master imaging and processing techniques in black-and-white first.

Mike D. Reynolds *is the dean of mathematics and natural science and a professor of astronomy at Florida Community College.*

What's inside the DSI?

Both the DSI III (color) and DSI PRO III (monochrome) use 1.4-megapixel (1360x1024) Sony ExView HAD CCD chips. The DSI III has this chip's color version. The pixels are square, which makes processing your final images easier. This chip gives the DSI III higher resolution and a field of view nearly four times larger than previous models.

Even without a fan or a water jacket, the DSI III has low thermal (heat) noise, which allows it to perform like more expensive CCD cameras. The DSI III has a built-in temperature sensor, which provides quick and accurate auto-dark frame subtraction, a must in calibrating images.

Both DSI III models come with *ENVISAGE*, Meade's camera-control software. New features include the ability to zoom in on a specific object, such as a star, resulting in sharper focus.

Testing and judgment

I tested the DSI III Pro with the optional CCD color filters at the 2008 Winter Star Party in the Florida Keys. For my tests, I used two telescopes: Meade's 14-inch RCX400 and Tele Vue's NP-127is refractor, owned by my friend and fellow astroimager Taber Manning.

At just 11.2 ounces (0.3 kilogram), the camera's weight was never an issue on either telescope. Connecting the camera to my laptop was easy. Before my first night session, I installed *ENVISAGE* on my laptop to check its compatibility with Microsoft's *Vista* operating system.

When you're in the field, it can be difficult to tell if a star is in focus. The DSI III and *ENVISAGE* make focusing easy. For a shortcut to rough focus, I first used a Meade 9mm reticle eyepiece on the telescope visually. Then, I took out the eyepiece and put the DSI III in its place. The 9mm eyepiece's focal plane is the same as the DSI III's. This procedure

Specifications

Meade Deep Sky Imager III

Chip: Sony EXview HAD color 1.4-megapixel CCD sensor; DSI PRO III equipped with Sony EXview HAD monochrome 1.4-megapixel CCD sensor (all other specifications are the same)
Pixel size: 6.45 microns square
USB capability: High-speed 2.0 only
Exposure times: 1/10,000-second to 1 hour
Housing: Coated die-cast aluminum
Weight: 11 ounces (312 grams)
Dimensions: 4" by 3.75" by 1.25" (102 mm by 95 mm by 32 mm)
Comes with: AutoStar Suite software with *ENVISAGE* imaging software and a 1¼" nosepiece
Price: $1,299

Meade's CCD Color Filter Set (optional) allows you to produce color images with the black-and-white version of its DSI III. All filters span 1¼" and are parfocal, which means you won't have to refocus when switching between filters. *Astronomy:* William Zuback

The Horsehead Nebula (B33) and the Flame Nebula (NGC 2024) in Orion are two of astroimagers' favorite objects. Meade's DSI III had enough dynamic range to record the bright star Zeta Orionis plus nebulous details. Mark Sibole

The Andromeda Galaxy (M31) is a celestial target that features bright star-filled areas bounded by dark dust lanes. The DSI III captured the high contrast in this object. Mark Sibole

The DSI III's sensor, a color 1.4-megapixel CCD chip (the DSI III PRO contains a monochrome chip), sits in a cast aluminum housing, which weighs 11 ounces (312 grams). *Astronomy*: William Zuback

Meade's Deep Sky Imager III uses an uncooled design. To make this work, engineers developed a way to reduce noise without a water jacket or fan. The design incorporates a built-in temperature sensor and requires no batteries. *Astronomy*: William Zuback

worked well for me on both telescopes. Once I had achieved a rough focus, I found it easy to use *ENVISAGE*'s focus feature. I could sit at my laptop and "observe" the focus, tweaking to achieve the sharpest image.

Using *ENVISAGE* made it easy to set parameters like exposure times, total number of images, or field rotation correction. Field rotation occurs when your telescope is not on a polar-aligned mount. Alt-azimuth mounts experience this problem. Field rotation is easily visible if you stack a series of images. *ENVISAGE* eliminates field rotation issues and controls stacking.

Stacking is an important feature of CCD imaging. It allows you to deal with problems that often occur in long exposures. Let's say you want a 15-minute exposure of the Horsehead Nebula (B33). If you take an exposure that long, you may experience vibration or stray light. On the other hand, if you take a hundred 10-second exposures, you can delete any bad images, and stack the good ones into an exceptional photograph.

With the DSI Pro III, I noticed how easy it was to use its filters. They are on a bar, which you slide to move to a different one. Even in the dark, it was easy to feel the filters click into place.

Meade's DSI III is a winner. Whether you choose color or monochrome, you'll feel like a pro when you use it.

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September web extras

Monthly web extras bring you additional research, interviews, photographs, and animations that our editors turned up while creating the magazine stories.

"The Cygnus Arm flexes its muscle" p. 18
Discover more about the Cepheid variable star XCygni.

"How astronomers cracked the Einstein code" p. 28
Numerical relativity researcher Manuela Campanelli narrates an animated black-hole merger.

"The coming solar superstorm" p. 38
See the Sun from the Hinode solar observatory.

"Ask astro" p. 60
What does "right ascension" mean? Why don't astronomers just say "ascension?"

"Discover 10 top Milky Way delights" p. 62
Find these gems with a Meade Autostar tour.

Dumbbell Nebula

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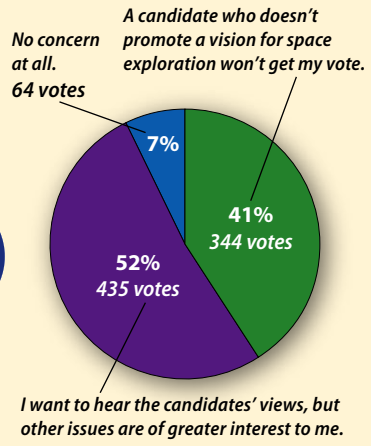
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64 votes
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7%
41%
344 votes
52%
435 votes
I want to hear the candidates' views, but other issues are of greater interest to me.

Total votes: 843

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Galaxy NGC 4589 lies in Draco

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TOURING DRACO
Senior Editor Michael E. Bakich takes you inside the constellation Draco.

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Alex Szalay of Johns Hopkins University and Curtis Wong of Microsoft's Next Media Research Group discuss the WorldWide Telescope's origins with Senior Editor Francis Reddy.

ALL IN A SPIN
Amateur astronomer Richard Miles tells how he measured an asteroid thought to be the fastest rotating natural object in the solar system.

This month's top blogs

Editors put their spin on current events in the staff blog. You can share your opinions on news headlines and popular culture, too.

1 LOTS TO SEE ON THE MOON
Gerald North's new book, *Observing the Moon: the modern astronomer's guide* is filled with lunar facts and observations. **BY MICHAEL E. BAKICH**

The Moon's north pole

2 OFF ORBIT
Astrocast, a nonprofit web channel that produces videos on astronomy, is designed to reach both beginning and advanced observers. **BY JEREMY McGOVERN**

3 A VISIT TO SPACE PLACE
Hidden in Madison, Wisconsin, Space Place is an excellent astronomy education and outreach facility. **BY DAVID J. EICHER**

It's showtime!

Our exclusive videos share how-to tips, explain science headlines, showcase equipment, and more.

Featured video

ARIZONA SKY VILLAGE
Senior Editor Michael E. Bakich tours the stargazer's paradise in the American Southwest.

Far left, clockwise: Joe and Gail Metcalf/Adam Block/NOAO/AURA/NSF; NASA/HST/Timothy Hamilton; NASA/JPL

Observing Basics

by Glenn Chaple

A sure bet for observing fun

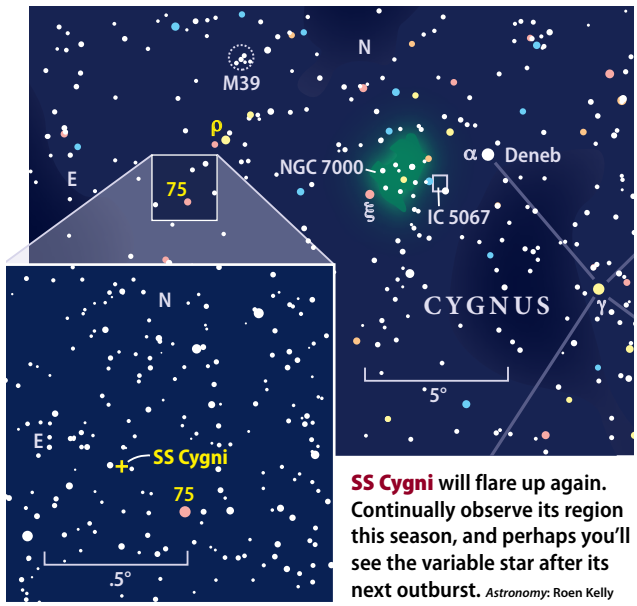
"I owe Rik Hill ten dollars." With those words, David Levy lured me into a lifelong addiction to the explosive variable star SS Cygni. Levy's account, in a 1980 issue of the now-defunct *Star and Sky* magazine, told of his friendly wager with Hill over the exact date of SS Cygni's next outburst. What was it about this star that would inspire amateur astronomers to gamble? I had to find out.

Since its discovery in 1896, SS Cygni has captivated astronomers. It ranks as one of the most popular objects in the American Association of Variable Star Observers' (AAVSO) observing program.

Unlike pulsating variable stars, typified by Mira (Omicron [o] Ceti) and Delta (δ) Cephei, SS Cygni owes its brightness changes to an interaction between the members of a close binary system: a small red star orbiting a white dwarf. Matter stolen from the former by the latter's gravity hurtles toward the white dwarf, forming a rapidly-spiraling accretion disk. Heightened activity in the accretion ring is believed to be the outburst's catalyst.

Once in outburst, SS Cygni will remain "up" for a week or two before fading back into quiescence. Because of their explosive nature, SS Cygni and other dwarf novae, as well as novae and supernovae, are classified as cataclysmic variables (CVs).

My adventure began with a 3-inch reflector and a star-hop from the 4th-magnitude star Rho (ρ) Cygni. Using the finder scope, I followed a pattern of stars from Rho to 75 Cygni, 2½° south and slightly east. Peering through the eyepiece, I discovered this ruddy-hued star is the "Aldebaran" of a V-shaped asterism reminiscent of Taurus' Hyades. I gently nudged the telescope eastward in the direction of the V's opening, arriving at a distinctive triangle of 9th- and 10th-magnitude stars — SS Cygni's lair. Because my 3-inch instrument could reach only 11th magnitude on a typical night, the star was nowhere to be seen. My target must have been in its quiescent or "down" state at around 12th magnitude.



SS Cygni will flare up again. Continually observe its region this season, and perhaps you'll see the variable star after its next outburst. *Astronomy*: Roen Kelly

According to Levy's article, outbursts occur every 50 days on average. Eager to witness the next event, I planned to observe SS Cygni each clear night.

Finding the star that first night took about 10 minutes. After a few evenings, I negotiated the route in less than a minute. Like the slot machine gambler who believes the next coin will hit the jackpot, I lugged my little telescope outside each night, positive that SS Cygni would be there to greet me.

I became so obsessed that even a broken finger suffered in an early evening tumble didn't deter me. Before heading to the emergency room, I scooped up my little reflector with my good hand and trudged outside, positive that I'd be rewarded for my efforts.

I peered into the eyepiece and an empty triangle peered back. SS Cygni was surely mocking me!

Then, one memorable night, an 8th-magnitude star shone brightly inside the triangle where black sky had been the previous evening. SS Cygni was "up!" This observation had me hooked. My addiction with the variable star continues to this day.

Now it's your turn to join David Levy, me, and other SS Cygni observers. Because outbursts occur every month or two, you can expect to capture several during an observing season.

Its unpredictable behavior and rather rapid increase in brightness at outburst mandates that you observe SS Cygni at least once nightly. Although a 6-inch scope will show the star during all stages, my experience in 1980 proves that a smaller instrument can still reveal it.

No one can predict the next flare-up of SS Cygni — it could be in outburst as you read this column. Based on its performance in recent months, I'll wager $10 that the star will pop up this month on the evening of September 15. Any takers?

Want more information on SS Cygni? Refer to an AAVSO article at www.aavso.org/vstar/vsots/0600.shtml. If you're looking for a reader-friendly handbook on variable-star observing in general, I recommend *David Levy's Guide to Variable Stars* (Cambridge University Press, 2005).

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: Blood drops in the sky. Clear skies!

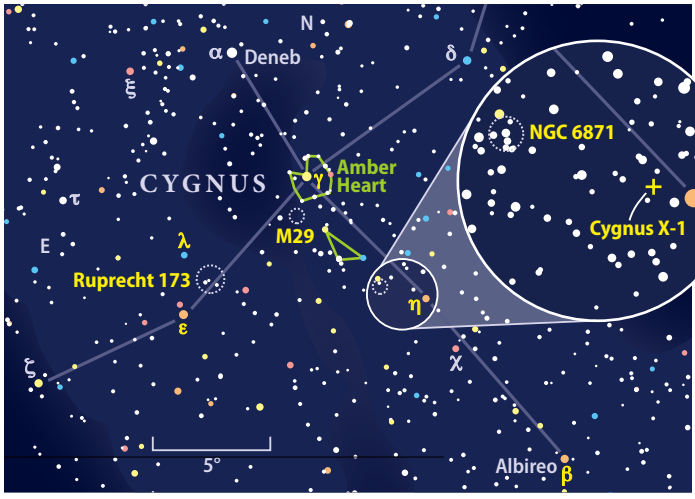
Binocular Universe

by Phil Harrington

The Cygnus Arm flexes its muscle

Can I lend you a hand? How about an entire arm — the Cygnus Arm, that is. The Milky Way has two major spiral arms named for the constellations in their proximity — Scutum-Centaurus and Perseus — and two minor arms — Sagittarius and Cygnus — along with at least two smaller spurs.

The Cygnus Arm, often called the Norma-Cygnus or Outer Arm, is the outermost of the four. To put things in perspective, the Orion Spur, a branch that curls between the Sagittarius and Perseus arms, hosts our solar system. As summer begins to wane, the wispy Cygnus Arm rises up from the south past the zenith, bringing with it several binocular targets.



The Cygnus Arm hosts several late summer binocular targets, highlighted by NGC 6871 and Cygni X-1. *Astronomy*: Roen Kelly

Let's start right in the middle of the Swan's body, at the star Sadr (Gamma [γ] Cygni). Observer Hope Harle-Mould from Kenmore, New York, writes that when he looks at Sadr through binoculars, he notices that "it is surrounded by a halo of dim stars that form a distinctive heart shape. The heart extends north-south and is a little rounded off at its southern tip. Amber-colored Sadr is in the center of the top of the heart, like a jewel in a pendant." Use your binoculars to see his **Amber Heart** asterism.

Keeping Sadr centered, look for a small, rectangular knot of misty starlight about halfway toward the field's southern edge. That's open cluster **M29** (NGC 6913). Although you may have to strain a little with binoculars up to about 10x to pull it out from its rich surroundings, larger glasses reveal it easily. My 20x80s have just enough oomph to show the group's brightest half dozen stars forming a pattern that reminds many of a short-handled dipper. In all, nearly 100 suns call M29 home.

Next, slide from Sadr along the Swan's eastern wing to the star Epsilon (ε) Cygni. Epsilon forms a right triangle with 4th-magnitude Lambda (λ) Cygni to its north and 6th-magnitude SAO 70406 to its northwest. If you have a good eye, you should also see that SAO 70406 is surrounded by several fainter suns. That small clump actually forms an open cluster that was missed by Charles Messier and the Herschels.

Known as **Ruprecht 173**, the cluster spans an area twice as large as the Full Moon. And that's the problem. The cluster is so large, and its stars so loosely packed, that it goes unnoticed through the narrow fields of most telescopes. The wider fields of binoculars, however, are perfect for showing that the eight brightest cluster stars form a pattern that looks just like a tiny version of the winter constellation Lepus the Hare. That's why I think of this as the Baby Bunny Cluster.

Returning again to Sadr, slowly sweep southward along the Swan's neck. You'll pass a flattened triangle along the way before bumping into Eta (η) Cygni, about halfway between Sadr and Albireo (Beta [β] Cygni). Eta is surrounded by fields of faint stardust. If you were looking here with X-ray vision, however, you would see a single bright point standing out from the crowd. That's the strong X-ray source known as **Cygnus X-1**, the Rosetta Stone of black holes.

Cygnus X-1 is a binary system, with the black hole pulling material off its 9th-magnitude blue-supergiant companion, which is listed in the Henry Draper catalog of stars as HDE 226868. As the material accelerates toward the speed of light, it gives off the powerful X-ray emissions that we can detect.

Although we can't see the black hole through binoculars — or through any optical telescope for that matter — we can just barely make out its forlorn companion star. Using the finder chart here, look for a very faint point just a quarter of a degree northeast of Eta.

Before moving on, can you also spot the compact open cluster **NGC 6871** near the northeastern edge of the field? Look for a brighter patch of Milky Way peppered by a few faint stars. Most binoculars will resolve an arc of three 7th-magnitude suns surrounded by another half dozen dimmer points.

Questions, suggestions, or observations? E-mail me at phil@philharrington.net. Until next time, remember that two eyes are better than one.

Find more challenge objects in the Swan at www.Astronomy.com/toc.

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About Your Professor

Dr. Frank Summers is an astrophysicist in the Office of Public Outreach at the Space Telescope Science Institute (STScI) in Baltimore, Maryland, where he presents the findings of the Hubble Space Telescope and developments in general astronomy to the public through various media and educational outlets. He received his M.S. and Ph.D. in astronomy from the University of California at Berkeley.

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Dr. Summers was a key member of the scientific advisory committee for the Academy-Award nominated IMAX film *Cosmic Voyage*. He also directed, co-wrote, and created the 3-D visualizations for the IMAX short film *Hubble: Galaxies Across Space and Time*, which won the Large Format Cinema Association's Best Short Film Award in 2004.

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Astro-Tech Voyager shown with optional **Astro-Tech AT102ED** 4" refractor (see below)

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The Voyager has automatic friction clutches that let you quickly point your scope at a target manually, then smoothly track it in any direction using Voyager's dual 120-tooth worm gear 360° manual slow-motion controls.

The review said the Voyager's "smooth slow motion controls" were one of the mount's many virtues. Their value was "immediately obvious . . . Couple them with the Voyager's stability, and it was a pleasure viewing at magnifications approaching 200x – something I can't say for most alt-azimuth mounts that you have to push by hand."

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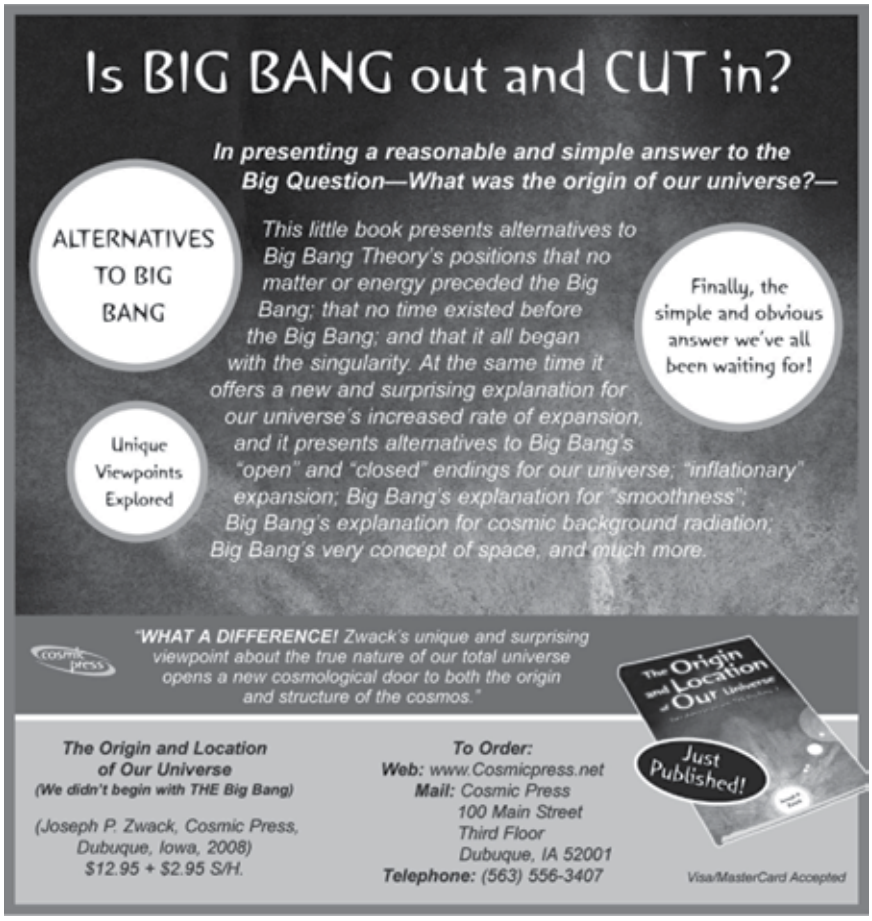
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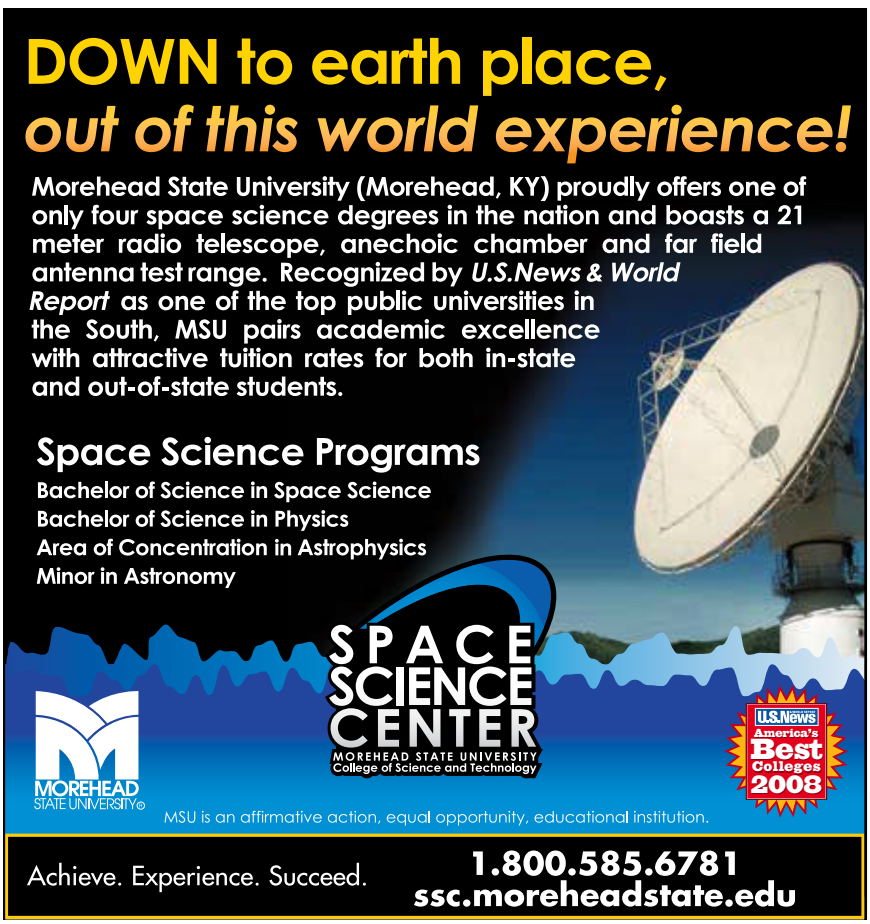
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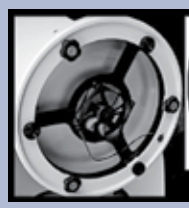
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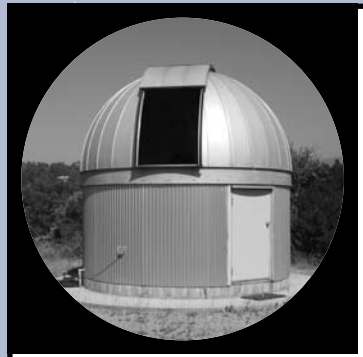

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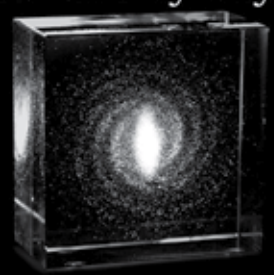

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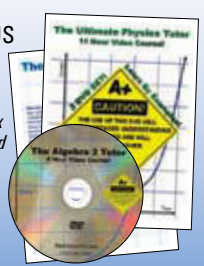

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reader gallery

Dark nebula van den Bergh 152 (10-inch Takahashi BRC-250 Baker Ritchey-Chrétien telescope at f/5 and 4-inch Takahashi FSQ-106 apochromatic refractor at f/5, Finger Lakes ProLine 16803 CCD camera, LRGB image with exposures of 5, 1, 1, and 1 hours, respectively) • Giovanni Benintende, Catania, Sicily

Star potential

Van den Bergh 152 is an odd-looking deep-sky object, more resembling a column of smoke than a future star-forming region. VdB 152 combines reflection (blue) and dark nebulosity, and astronomers classify it as a molecular cloud. The brighter region at the top scatters light from an embedded star. The rest of the cloud blocks the light from stars and brighter gas behind it. VdB 152 sits in Cepheus about 1,400 light-years away.

^ From the south, Mauna Kea's reddish basaltic rocks and dark-red cinder cones contrast with the white- and chrome-capped observatories and the dark, star-filled sky. Above the observatories, the Big Dipper seems to pour its contents onto the horizon. (Canon EOS 300D digital SLR, Canon 8mm fisheye lens at f/4, ISO 800, 1-minute tripod-mounted exposure) • Tunç Tezel, Bursa, Turkey

^ Venus and Saturn highlight this image, taken through the slit of the imager's observatory. The "sickle" of Leo the Lion lies above the pair, with the 1st-magnitude star Regulus to the left. (Nikon D70S DSLR camera, 29mm lens at f/4.5, ISO 200, 5-second exposure, taken June 30, 2007, at 9:29 P.M. MDT) • Richard McCoy, Mead, Colorado

> Three dark nebulae, Barnard 148, Barnard 149, and Barnard 150 lie roughly 2° south of magnitude 3.4 Eta (η) Cephei. (4-inch Tele Vue NP-101 apochromatic refractor at f/5.4, SBIG ST-2000XM CCD camera, LRGB image with exposures of 408, 132, 66, and 66 minutes, respectively). • Bernhard Hubl, Schlierbach, Austria

reader gallery

Send your images to: *Astronomy* Reader gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of image and complete photo data: telescope, camera, and exposure information. To submit images electronically, visit www.contribute.kalmbach.com.

Emission nebula IC 2944 looks unlike the same object that appeared in *Astronomy*'s June Reader Gallery. Here, the imager used narrowband filters to highlight different details than you'll see in a visible-light image. Look closely in the brightly lit region for dark globules made of opaque dust clouds. (5.2-inch Astro-Physics apochromatic refractor at f/6, Apogee Alta 16803 CCD camera, Astrodon Hα (mapped to green), SII (mapped to red), and OIII (mapped to blue) filters, with exposures of 3, 3, and 4 hours, respectively) • Ken Crawford, Rancho del Sol Camino, California

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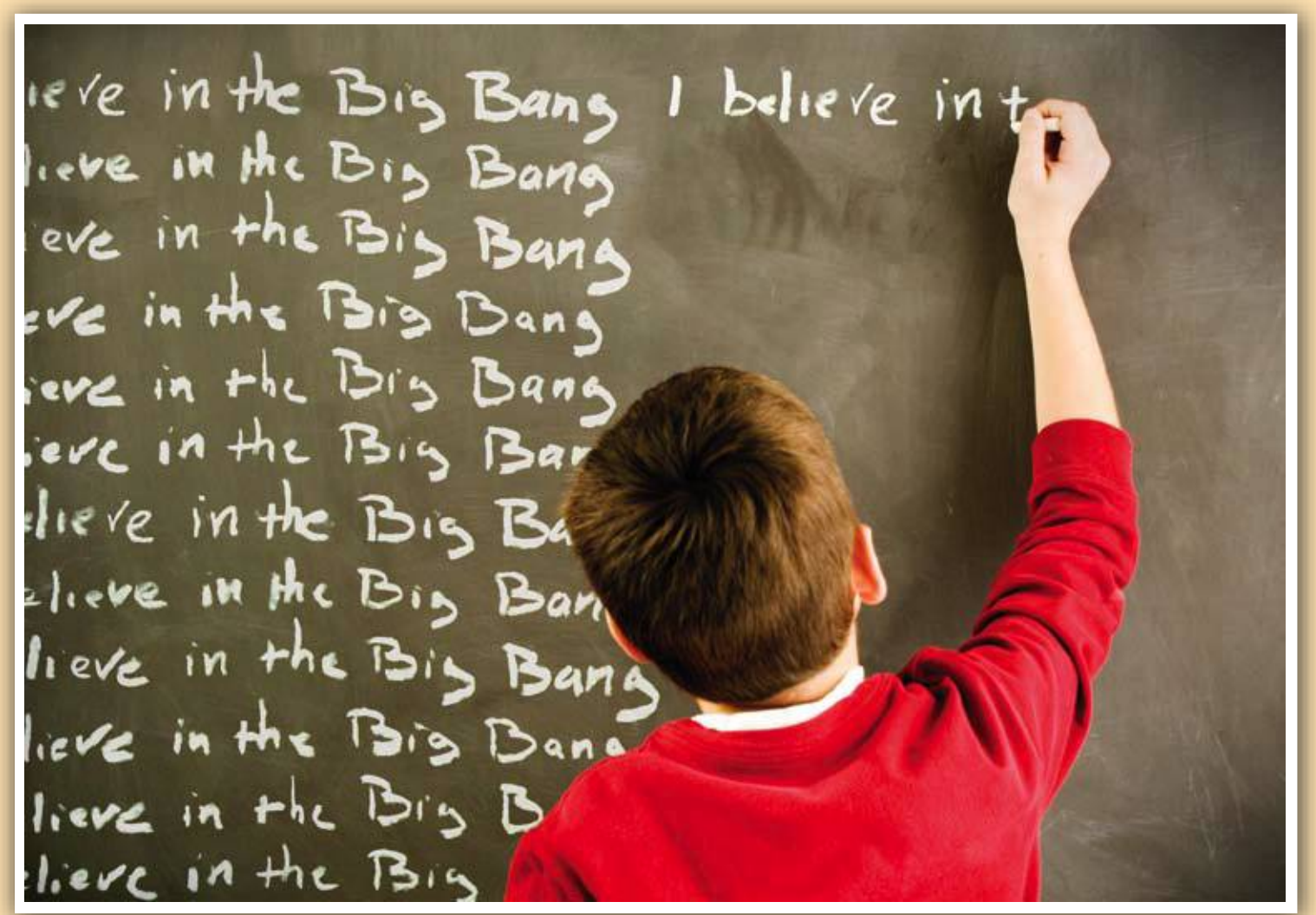
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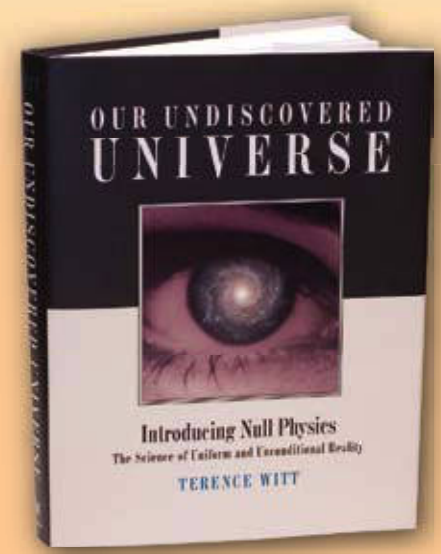

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